APPENDIX H – Lower USDW Letter from Frommelt (2009)

Archer Daniels Midland Company
4666 Faries Parkway
Decatur, IL 62526
T 217.424.5200

September 29, 2009 **Via Overnight Service**

Ms. Terri Blake Meyers, L.P.G
Illinois Environmental Protection Agency
Manager, RCRA - Groundwater Assistance Unit, Permit Section, Bureau of Land
1021 N. Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276

Subject: Lowermost Underground Source of Drinking Water (USDW)
Archer Daniels Midland Company – UIC Permit UIC-012-ADM

Dear Ms. Blake-Meyers:

On July 27, 2009, ADM submitted via email a draft permit amendment for its UIC Permit for carbon sequestration. Included with that email was a final copy of a report summarizing the investigation results to determine the lowermost USDW and a proposal for monitoring the lowermost USDW.

ADM is hereby re-submitting this final report in hardcopy for your review. Once you have had a chance to review, please let me know as we would like to schedule a meeting to discuss.

If you have questions regarding this submittal please contact me at (217) 451-6330.

Sincerely,

Dean Frommelt
Division Environmental Manager
Archer Daniels Midland – Corn Processing

cc: Kevin Lesko, IEPA
Mark Burau, ADM
Mark Carroll, ADM
Rob Finely, ISGS
Sallie Greenburg, ISGS

Last revised: June 23, 2009
RJF Review July 20, 2009

Summary

Data regarding the Lowermost Underground Source of Drinking Water at the Illinois Basin Decatur Project

Introduction

Field investigations were conducted at the ADM ethanol plant in Decatur to determine the lowermost underground source of drinking water (USDW). A USDW is defined based on its hydraulic conductivity ($K > 1x10^{-4}$ cm/sec) and its water quality (total dissolved solids <10,000 mg/L). Available data indicated that USDWs may be present in the Pennsylvanian bedrock and the upper St. Peter Sandstone (Ordovician age bedrock). To identify these USDWs, the following investigations were conducted:

1) Drill stem testing, water sampling, and logging of the St. Peter Sandstone in ADM CCS No. 1
2) Geophysical logging of bedrock formations in groundwater monitoring well
3) Coring, packer testing and water sampling of Pennsylvanian bedrock in groundwater monitoring well

Results from these investigations are summarized. Details regarding the methods used and results are described in several attachments. This summary concludes with a proposal for monitoring the lowermost USDW.

Testing of the St. Peter Sandstone

During drilling of ADM's CCS #1 well, a drill stem test (DST) was conducted in the upper 30 feet of the 210 ft thick St. Peter Sandstone. This DST provided data to calculate the hydraulic conductivity and a water sample to test total dissolved solids (TDS). TDS was determined by two labs. For the sample collected in the DST sample chamber, Prairie Analytical Systems (Springfield, IL) determined TDS to be 4,540 mg/L while the ISGS determined it to be 5,420 mg/L. Thus, water in the upper section of the St. Peter is below the USDW definition.

Using the DST data, the permeability of the St. Peter Sandstone was estimated to range from 41.5 to 144 millidarcies (mD), with a best estimate of 100 mD. Values of permeability (k) can be converted to hydraulic conductivity ($K = k\rho g/\mu$) if the fluid viscosity (μ) and density (ρ) are known. Available algorithms to estimate brine viscosity provide a range of values—0.70 to 0.84 centipoise. For $\rho = 1000$ kg/m^3 and $\mu = 0.70$ centipoise or $7.0x10^{-4}$ kg/m sec, 100 mD converts to $1.38x10^{-4}$ cm/sec. For $\rho = 1000$ kg/m^3 and $\mu = 0.84$ centipoise or $8.4x10^{-4}$ kg/m sec, 100 mD converts to $1.15x10^{-4}$ cm/sec. These estimates of hydraulic conductivity are slightly greater than the USDW definition. The range of permeability values (41.5 to 144 mD) converts to $5.7x10^{-5}$ to $2.0x10^{-4}$ cm/sec assuming a fluid viscosity of 0.70 centipoise.

Other Geophysical Logging

During drilling of ADM's CCS #1 well, the borehole was logged prior to the installation of the steel casing. This open-hole logging included Schlumberger's Platform Express (PEX), which includes neutron and density logs to determine porosity and fluid type and several resistivity logs (depth of investigation ranged from borehole to 90 inches) to determine fluid salinity. Based on these and other logs, the porewater over the entire 210 ft interval in the St. Peter was estimated using the Archie equation (assumed cementation factor, m= 1.85) to have salinity ranging from 7,900 to 12,600 mg/L (NaCl equivalent). Salinity was lowest in the shallower portion of the St. Peter and highest in the deeper portion of the St. Peter. On a pore volume weighted basis, the mean salinity was estimated to be 11,300 mg/L NaCl equivalent, which means all the salinity was due to sodium (Na) and chloride (Cl) in solution.

Table 1. Summary of TDS estimates based on DST sample results

Interval (feet below ground surface)	Salinity estimated from geophysical logs (mg/L)	TDS, lab 1 (mg/L)	TDS, lab 2 (mg/L)	TDS estimate, lab 1 (mg/L)	TDS estimate, lab 2 (mg/L)
3252-3262	7,947	4,540	5,420	4,540	5,420
3262-3366	10,701			6,113	7,298
3366-3454	12,598			7,197	8,592

Lab 1= Prairie Analytical, Springfield, IL
Lab 2= ISGS, Champaign, IL

This NaCl-equivalent salinity can be converted to TDS using published conversion factors or estimated using brine geochemistry. The TDS values were estimated for three intervals using TDS values from the DST sample (Table 1), which was collected from a depth of 3239 to 3284 feet below ground surface. TDS values from a single water sample were determined by two labs. These values were used to convert salinity to TDS assuming that the salinity of the first interval was equivalent to the lab-determined TDS value. The TDS estimates for deeper intervals were adjusted using a linear correction (TDS2= Sal2/Sal1 * TDS1). Both estimates of TDS are below the 10,000 mg/L limit for USDWs.

Testing of the Pennsylvanian Bedrock

Geologic materials and water samples were collected in MMV-04B to a depth of 504 feet below ground surface. This well is located approximately 1,850 feet northwest of CCS #1. HQ-sized core were collected from a depth of 146 to 504 feet, allowing the lithology and stratigraphy to be identified. Pennsylvanian bedrock was recovered from this borehole and included fine-grained sandstone, limestone, siltstone, shale and some coal. None of the rock appeared to be capable of producing much water. Seven packer tests were conducted in the borehole. These packer tests were run at depths from 162 to 454 feet and indicated that the Pennsylvanian bedrock had a maximum hydraulic conductivity of 3×10^{-6} cm/sec and a minimum K $<10^{-8}$ cm/sec. Thus, this bedrock K is less than the value in the USDW definition.

Water quality sampling and geophysical logging indicated a sharp interface between fresh groundwater and “brine” at a depth of 310 to 320 feet. A groundwater sample collected at a depth of 300 feet had a TDS concentration of 1,550 mg/L, while a sample collected at a depth of 380 feet had a TDS concentration of 25,300 mg/L.

A monitoring well was completed in MMV-04B this borehole at a total depth of 295 feet. This well was screened from 275 to 295 feet and had a sand pack from 265 to 295 feet. The monitoring well was developed, but sampling results are pending.

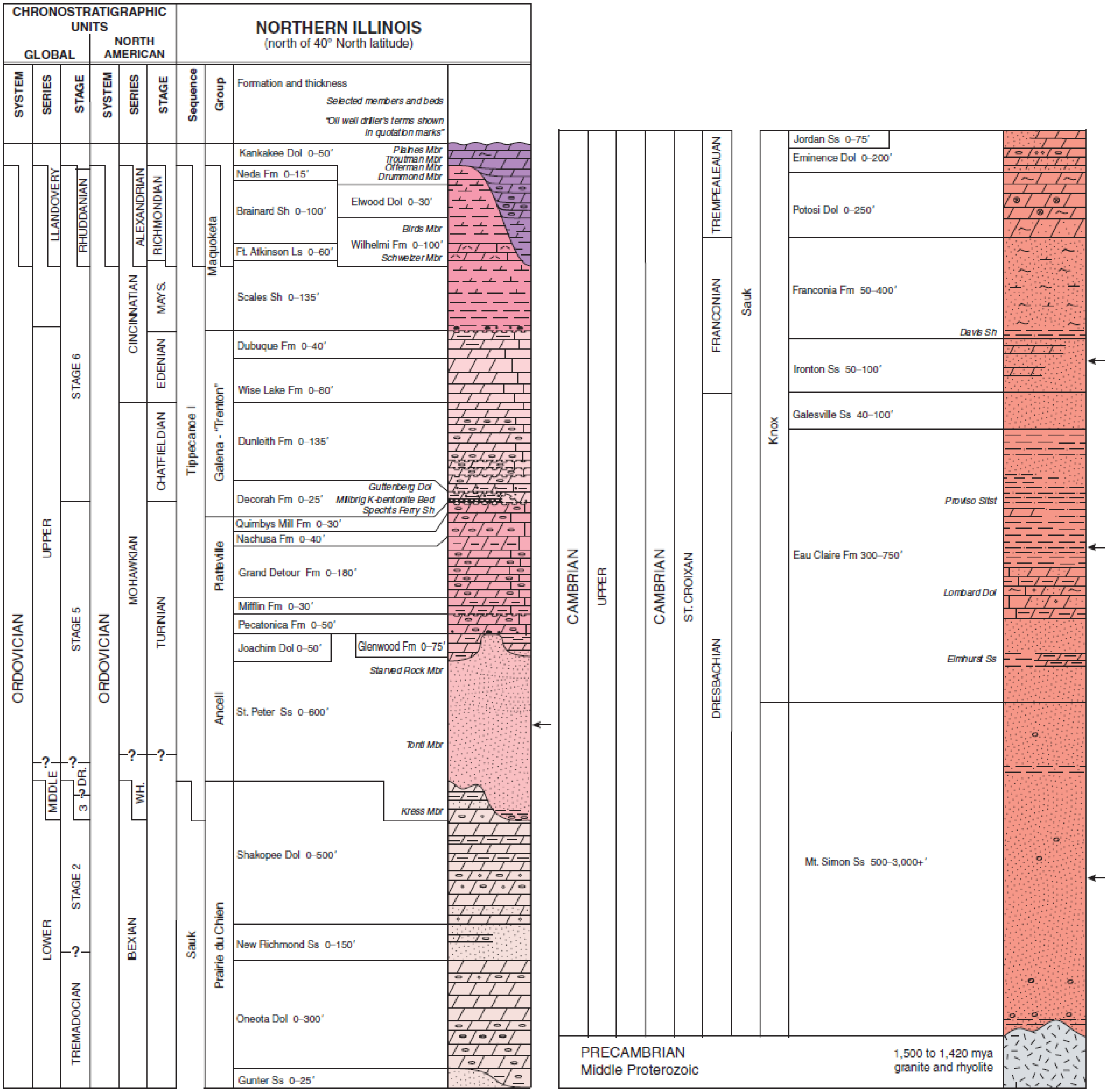
Summary and Proposed Monitoring for the Lowermost USDW

Data collected at the site demonstrate that some of the Pennsylvanian bedrock has groundwater with TDS less than 10,000 mg/L, but its hydraulic conductivity is below 10^{-4} cm/sec. The St. Peter Sandstone also has groundwater with TDS less than 10,000 mg/L, but its hydraulic conductivity is slightly greater than 10^{-4} cm/sec.

Although the Pennsylvanian bedrock does not meet both elements of the USDW definition, we propose to monitor groundwater in the Pennsylvanian bedrock because of its potential for domestic use. Groundwater in the Pennsylvanian bedrock can be monitored using wells completed like MMV-04B. A total of three wells can be installed surrounding the CO_2 injection well. Three wells should be adequate to define any seasonal variations in the shallow bedrock groundwater and to detect any leaked CO_2.

The USDW present in the St. Peter Sandstone can be protected by monitoring the first aquifer above the Mt. Simon Sandstone, the Ironton-Galesville (Figure 1), using the verification well. Monitoring the Ironton-Galesville is expected to detect any CO_2 leaked from the Mt. Simon Sandstone faster than directly monitoring in the St. Peter Sandstone. In other words, early detection of CO_2 in the Ironton-Galesville may better protect the St. Peter from out-of-zone CO_2 migration through early detection and opportunity for mitigation before actual CO_2 entry into the St. Peter. Because these formations are so deeply buried, monitoring with a single well is adequate to detect any changes in geochemistry. In addition, borehole logging with the reservoir saturation tool (RST) in the verification well should provide additional data to verify that no CO_2 is leaking from the Mt. Simon Sandstone. RST uses pulsed neutron techniques to determine reservoir saturation, lithology, porosity, and borehole fluid profiles. Additional information about this tool can be found in UIC Form 4E. In summary, the verification well can be used to monitor groundwater quality and formation pressure in the Ironton-Galesville and collect RST data from the Mt. Simon Sandstone through the St. Peter Sandstone. These data will help us determine if any CO_2 moves from the Mt. Simon Sandstone and into any overlying formations above the primary Eau Claire shale seal.

Figure 1. Stratigraphic column of the Ordovician through Precambrian bedrock in northern Illinois (from Kolata, 2005. Bedrock Geology of Illinois, Illinois Map 14)



Appendices

A. **Detailed Report— Drill Stem Test of the St. Peter Sandstone-- Geochemical Results**
B. **Detailed Report—Drill Stem Test Report**
C. **Detailed Report-- Analysis of DST-1 ADM – CCS #1**
D. **Detailed Report— Interpretation of Wireline Log Data in the St. Peter Sandstone**
E. **Detailed Report— Testing of the Pennsylvanian Bedrock**

Drill Stem Test of the St. Peter Sandstone—Geochemical Results

Ivan G. Krapac, ISGS Draft: May 20, 2009

Introduction

A drill stem test (DST) was conducted at the Illinois Basin Decatur Project CO_2 injection well on March 6 and 7, 2009. The primary goal of the test was to collect a water sample from the St. Peter to determine if the total dissolved solids (TDS) would exceed the USDW criteria of 10,000 mg/L TDS. In addition, a pressure fall-off test was conducted to determine the hydraulic conductivity of the St. Peter.

Trilobite Testing Inc. (Hays, Kansas) ran a conventional bottomhole DST. The test interval was 3255 to 3300 feet below the Kelly Block (KB) or 3239 to 3284 feet below ground surface. The test was conducted in an 8.75 inch diameter borehole, which had a total depth of 3,300 feet (KB). The tested interval represents the lower portion of the Galena-Platteville limestone and the upper portion of the St. Peter Sandstone (top of St. Peter at 3270 feet). The packer was set in the Galena-Platteville to enable sealing of the mechanical packer. Because the porosity and permeability of the Galena-Platteville is considered to be much lower than the St. Peter, it was believed that water collected during the DST would flow from the St. Peter. During the DST, 1,772 gallons of water was recovered. This water rose 3,000 feet into the drill pipe. The recovered water was described as follows: 147 gallons of muddy water and 1,625 gallons of water. These data indicate that the St. Peter was not heavily damage by the drilling process and that the hydraulic head in the St. Peter is approximately 250 feet below ground surface. The downhole temperature probe in the DST tool recorded the fluid temperature at 97.5 °F.

Geochemical Methods

As the DST was conducted, water flowed through the DST tool into the drill string. As the DST tool was brought to surface, water samples were collected in five gallon buckets as each joint of a 30 or 60 foot drill string was broken. Field parameters such as pH, EC, temperature, and alkalinity were attempted to be measured for each bucket. An oily film present on the surface of the water caused the electrodes to foul and inhibited field measurements to be conducted. It was concluded that the oily material was likely an artifact of the pipe thread lubricant used in the drilling operation.

A water sample was collected and analyzed from the last drill string located immediately above the DST tool and is identified as DST-10 in this report. This sample was collected because it was thought to be somewhat representative of the St. Peter formation water because it was the last water that flowed from the St. Peter formation and through the DST tool. This sample also served as a backup sample if the DST tool failed to collect an adequate water sample. The water sample collected from the DST tool sample chamber is identified as DST-1. This sample was collected directly from the sample chamber and placed directly in the appropriate sample bottles and filter assembly. Alkalinity, pH, temperature and EC were measured on DST-1

The samples for anions, cations, and alkalinity were filtered through 0.45 μm filters on site and preserved as required. All samples were kept on ice in the field and refrigerated at 4°C in the laboratory until analyzed. Electrical conductivity, pH, and temperature were determined in the field using electrodes according to standard methods (American Public Health Association [APHA], 1992).

The water samples were submitted for cation, anion, and TDS analysis to laboratories within the Illinois State Geological Survey, the Illinois State Water Survey, and Prairie Analytical Systems, Incorporated (Table 1). Anion concentrations were determined by ion chromatography (O'Dell et al., 1984, method EPA300.0), and cation concentrations by inductively coupled argon plasma spectrophotometry (ICP- method EPA 200.7 and APHA, 1992) or ICP-MS (method EPA 200.8). TDS was determined according to APHA (1992).

Data Quality

There was good agreement between the concentration data measured by the various laboratories with relative differences between laboratories generally less than 20%. Anion and cation equivalents and calculated TDS were determined using Geochemist's Workbench (Bethke and Yeakle, 2007) based on input data presented in Table 1. Anion-cation balance and the difference between calculated and measured TDS for each of the data sets were within quality control limits set by APHA (1992) and are presented in Table 1.

Discussion

Constituent concentrations in sample DST-1 and DST-10 were comparable for most constituents. Comparison of constituent concentrations determined in samples DST-1 and DST-10 to primary and secondary drinking water standards suggested that, with the exception of Fe, Mn, Pb, SO_4, and TDS, sample concentrations were less than the drinking water standard concentrations. Lead (Pb) was detected at a greater concentration than the drinking standard in sample DST-10 but not in DST-1, which may be due to the use of a lead based lubricant in the drilling process.

Iron, manganese, and sulfate concentrations, although exceeding secondary drinking water standards, would likely not impact human health but rather affect the aesthetics of the water by likely causing staining on plumbing fixtures. TDS was greater than the secondary drinking water standard but less than the 10,000 mg/L USDW limit. Chemical concentrations in the DST water samples would suggest that the St. Peter sand could be considered a USDW.

References

American Public Health Association, 1992. *Standard Methods for the Examination of Water and Wastewater*- 18th Edition, American Public Health Association.

Bethke, C.M. and S. Yeakel, 2007, The Geochemist's Workbench Release 7.0: Reaction Modeling Guide: Urbana, University of Illinois Urbana-Champaign, 84 p. [http://www.geology.uiuc.edu/Hydrogeology/hydro_gwb.htm]

O'Dell, J.W., J.D. Psass, M.E. Gales, and G.D. McKee, 1984. *Test Method- The Determination of Inorganic Anions in Water by Ion Chromatography- Method 300*, U.S. Environmental Protection Agency, EPA-600/4-84-017.

Wood, W.W., 1976. Guidelines for collection and field analysis of groundwater samples for selected unstable constituents, in US Geological Survey, Techniques for Water Resources Investigations, Chapter D-2, 24 p.

Table 1. Chemical composition of drill stem test water samples collected from the St. Peter Sandstone at Archer Daniels Midland well (CCS #1), Decatur IL. DST-1 was collected directly from the DST water sample chamber. DST-10 was collected from drill pipe immediately above the DST sample chamber.

Constituent	**DST-1 Prairie Analytical (mg/L)**	**DST-1 ISWS/ISGS (mg/L)**	**DST-10 Prairie Analytical (mg/L)**	**DST-10 ISWS/ISGS (mg/L)**	**Drinking Water Standard (mg/L)**
Al	ND	<0.037	ND	<0.037	NA
As	<0.0050	<0.108	<0.0050	<0.108	0.010
As (graphic furnace)	ND	<0.00095	ND	ND	0.010
B	ND	2.86	ND	2.86	NA
Ba	0.162	0.163	0.164	0.212	2
Be	<0.0040	<0.00055	<0.0040	<0.00055	0.004
Ca	128	134	146	148	NA
Cd	<0.0010	<0.012	<0.0010	<0.012	0.005
Co	ND	<0.013	ND	<0.013	NA
Cr	ND	<0.0058	ND	<0.0058	NA
Cu	<0.0050	<0.00079	<0.0050	<0.00079	1.3
Fe	4.40	4.90	<0.100	0.520	0.3
K	40.4	56.3	41.6	57.8	NA
Li	<0.0100	1.34	<0.0100	2.07	NA
Mg	49.4	55.5	52.9	57.6	NA
Mn	1.17	1.10	1.14	1.12	0.05
Mo	ND	0.159	ND	0.026	NA
Na	1490	1672	1510	1650	NA
Ni	ND	0.036	ND	0.026	NA
P	ND	<0.063	ND	<0.063	NA
Pb	<0.0050	<0.041	0.0922	<0.041	0.015
S	ND	134	ND	122	NA
Sb	ND	<0.059	ND	<0.059	NA
Se	ND	<0.131	ND	<0.131	NA
Si	ND	6.59	ND	6.66	NA
Sn	ND	<0.086	ND	<0.086	NA
Sr	ND	7.49	ND	8.31	NA
Ti	ND	<0.00056	ND	<0.00056	NA
Tl	<0.0020	0.023	<0.0020	0.024	0.002
V	ND	<0.047	ND	<0.047	NA
Zn	0.0292	0.0611	0.112	0.0657	5
F	ND	3.03	ND	3.31	2
Br	11.4	13.0	11.7	13.1	NA
Cl	2400	2384	2330	2403	NA
SO_4	295	404	287	394	250
SO_4 by cal. of S	ND	401	ND	366	NA
pH	ND	6.97	ND	ND	6.5-8.5
EC (Ms/cm)	ND	11.5	ND	9.8	NA
DO	ND	1.5	ND	ND	NA
Alkalinity (mg/L as $CaCO_3$)	ND	268	ND	266	NA
TDS (measured)	4540	5420	4620	5240	500/10,000
TDS (calculated)	4420	5144	4381	5142	NA
TDS difference	1.0[a]	1.1[a]	1.1[a]	1.0[a]	NA
Temperature (C)	ND	26.5	ND	28.7	NA
Anion/Cation Balance (%)	+1.7[a]	+2.8[a]	+4.5[a]	+2.5[a]	NA

ND= not determined

NA= not applicable or no standard

[a] = Within acceptable criteria for correctness of analyses (APHA. 1992. p.1-12)

TRILOBITE TESTING, INC.

DRILL STEM TEST REPORT

Prepared For: **ADM Co**

PO Box 1470
Decatur IL 62525

ATTN: Chuck Wiles

5-16N-3E Macon IL

CCS #1

TEST REPORT

TRILOBITE TESTING, INC.

DRILL STEM TEST REPORT

Prepared For: **ADM Co**

PO Box 1470
Decatur IL 62525

ATTN: Chuck Wiles

5-16N-3E Macon IL

CCS #1

Start Date: 2009.03.06 @ 20:39:02
End Date: 2009.03.07 @ 07:58:30
Job Ticket #: 32384 DST #: 1

Trilobite Testing, Inc
PO Box 1733 Hays, KS 67601
ph: 785-625-4778 fax: 785-625-5620

DRILL STEM TEST REPORT

Trilobite Testing, Inc

ADM Co

PO Box 1470
Decatur IL 62525

ATTN: Chuck Wiles

CCS #1

5-16N-3E Macon IL

Job Ticket: 32384 **DST#: 1**

Test Start: 2009.03.06 @ 20:39:02

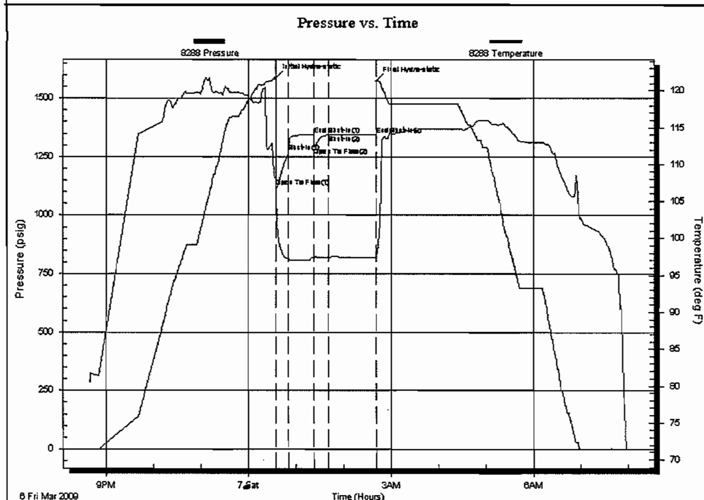
GENERAL INFORMATION:

Formation:	**St Peter**		
Deviated:	No Whipstock: ft (KB)	Test Type:	Conventional Bottom Hole
Time Tool Opened:	00:34:45	Tester:	Jack Fox
Time Test Ended:	07:58:30	Unit No:	29
Interval:	**3255.00 ft (KB) To 3300.00 ft (KB) (TVD)**	Reference Elevations:	690.00 ft (KB)
Total Depth:	3300.00 ft (KB) (TVD)		675.00 ft (CF)
Hole Diameter:	8.75 inches Hole Condition: Fair	KB to GR/CF:	15.00 ft

Serial #: 8288 **Inside**

Press@RunDepth:	1342.96 psig @	3294.01 ft (KB)		Capacity:	7000.00 psig
Start Date:	2009.03.06	End Date:	2009.03.07	Last Calib.:	2007.07.16
Start Time:	20:39:02	End Time:	07:58:30	Time On Btm:	2009.03.07 @ 00:34:30
				Time Off Btm:	2009.03.07 @ 02:41:15

TEST COMMENT: IF BOB in 1 mn Very Strong blow
FF BOB ASAO dying back to surface in 20 mn



PRESSURE SUMMARY

Time (Min.)	Pressure (psig)	Temp (deg F)	Annotation
0	1585.96	108.26	Initial Hydro-static
1	1119.57	108.03	Open To Flow (1)
17	1271.97	97.16	Shut-In(1)
49	1343.82	97.39	End Shut-In(1)
50	1289.99	97.37	Open To Flow (2)
67	1342.96	97.47	Shut-In(2)
127	1344.95	97.41	End Shut-In(2)
127	1572.88	97.49	Final Hydro-static

Recovery

Length (ft)	Description	Volume (bbl)
2759.00	Water	38.70
248.00	Muddy Water	3.48

Gas Rates

	Choke (inches)	Pressure (psig)	Gas Rate (Mcf/d)

DRILL STEM TEST REPORT

TOOL DIAGRAM

TRILOBITE TESTING, INC

ADM Co

PO Box 1470
Decatur IL 62525

ATTN: Chuck Wiles

CCS #1

5-16N-3E Macon IL

Job Ticket: 32384 **DST#: 1**

Test Start: 2009.03.06 @ 20:39:02

Tool Information

Drill Pipe:	Length:	3236.00 ft	Diameter:	3.80 inches Volume:	45.39 bbl	Tool Weight:	2500.00 lb
Heavy Wt. Pipe:	Length:	0.00 ft	Diameter:	0.00 inches Volume:	0.00 bbl	Weight set on Packer:	30000.00 lb
Drill Collar:	Length:	0.00 ft	Diameter:	0.00 inches Volume:	0.00 bbl	Weight to Pull Loose:	75000.00 lb
				Total Volume:	45.39 bbl	Tool Chased	0.00 ft
Drill Pipe Above KB:		10.00 ft				String Weight: Initial	58000.00 lb
Depth to Top Packer:		3255.00 ft				Final	72000.00 lb
Depth to Bottom Packer:		ft					
Interval betw een Packers:		45.02 ft					
Tool Length:		74.02 ft					
Number of Packers:		2	Diameter:	7.50 inches			

Tool Comments:

Tool Description	Length (ft)	Serial No.	Position	Depth (ft)	Accum. Lengths	
Shut In Tool	5.00			3231.00		
Sampler	3.00			3234.00		
Hydraulic tool	5.00			3239.00		
Jars	5.00			3244.00		
Safety Joint	2.00			3246.00		
Packer	5.00			3251.00	29.00	Bottom Of Top Packer
Packer	4.00			3255.00		
Stubb	1.00			3256.00		
Perforations	5.00			3261.00		
Change Over Sub	0.50			3261.50		
Blank Spacing	32.00			3293.50		
Change Over Sub	0.50			3294.00		
Recorder	0.01	8288	Inside	3294.01		
Recorder	0.01	6773	Outside	3294.02		
Perforations	3.00			3297.02		
Bullnose	3.00			3300.02	45.02	Bottom Packers & Anchor
Total Tool Length:	**74.02**					

TRILOBITE TESTING, INC

DRILL STEM TEST REPORT

FLUID SUMMARY

ADM Co

PO Box 1470
Decatur IL 62525

ATTN: Chuck Wiles

CCS #1

5-16N-3E Macon IL

Job Ticket: 32384 **DST#: 1**

Test Start: 2009.03.06 @ 20:39:02

Mud and Cushion Information

Mud Type:	Gel Chem	Cushion Type:		Oil API:	deg API
Mud Weight:	9.00 lb/gal	Cushion Length:	ft	Water Salinity:	7000 ppm
Viscosity:	80.00 sec/qt	Cushion Volume:	bbl		
Water Loss:	6.80 in³	Gas Cushion Type:			
Resistivity:	ohm.m	Gas Cushion Pressure:	psig		
Salinity:	ppm				
Filter Cake:	inches				

Recovery Information

Recovery Table

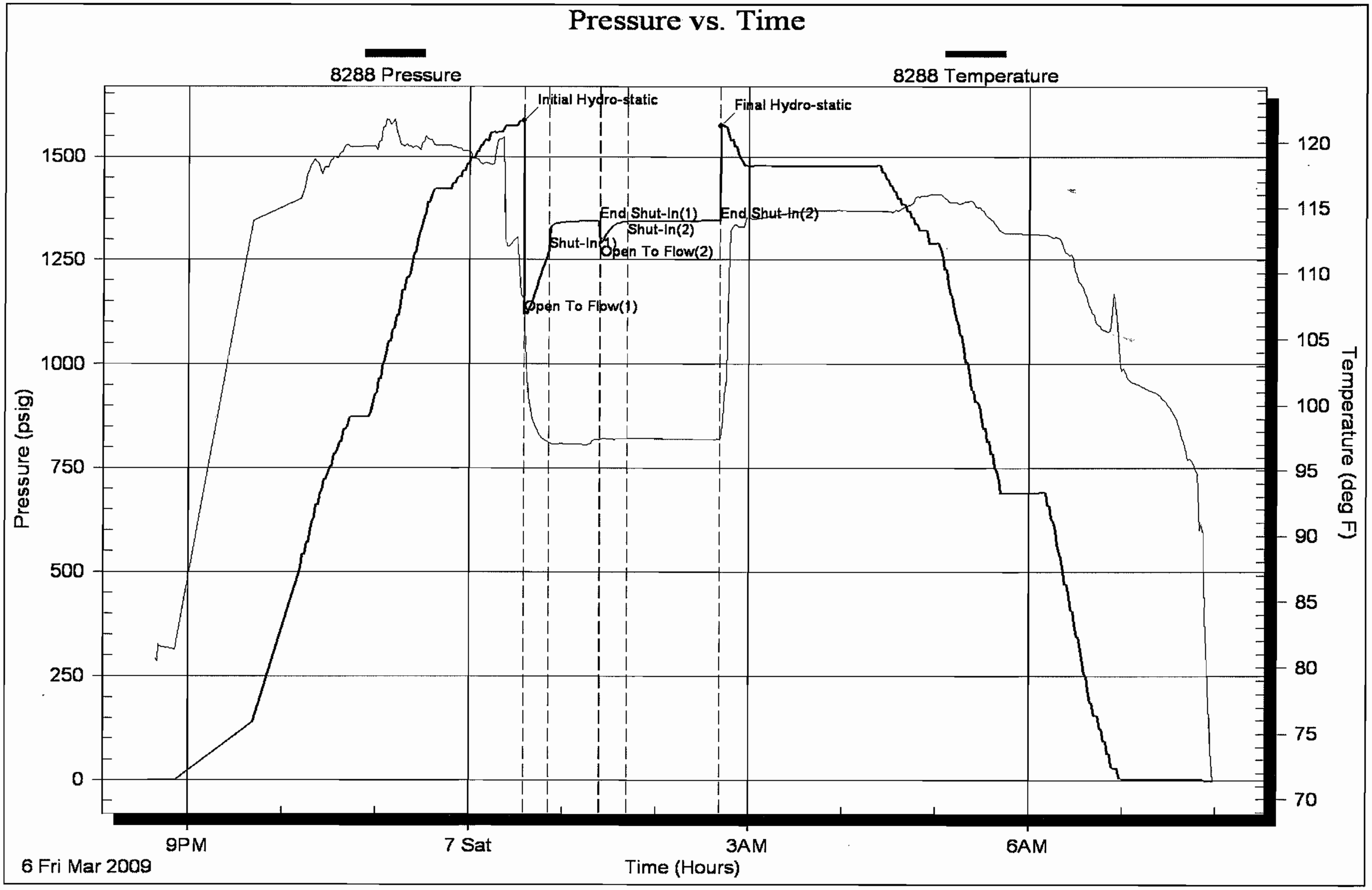
Length ft	Description	Volume bbl
2759.00	Water	38.702
248.00	Muddy Water	3.479

Total Length: 3007.00 ft Total Volume: 42.181 bbl

Num Fluid Samples: 0 Num Gas Bombs: 0 Serial #:

Laboratory Name: Laboratory Location:

Recovery Comments:



Pressure vs. Time
8288 Pressure
8288 Temperature
Initial Hydro-static
Final Hydro-static
End Shut-In(1)
End Shut-In(2)
Shut-In(2)
Shut-In(1)
Open To Flow(2)
Open To Flow(1)
1500
1250
1000
750
500
250
0
Pressure (psig)
120
115
110
105
100
95
90
85
80
75
70
Temperature (deg F)
9PM
7 Sat
3AM
6AM
6 Fri Mar 2009
Time (Hours)

Well Test SOLUTIONS

10819 Olympia Drive
Houston, Texas 77042
(713) 975-6260

gary@welltestsolutions.com

Analysis of DST-1 ADM – CCS No.1

By
Gary E. Crawford
June 5, 2009

Summary

An open-hole Drill Stem Test (DST) was conducted on the ADM CCS No.1 on March 6, 2009. The test consisted of an initial flow period of 16 minutes, an initial shut-in of 30 minutes, a final flow of approximately 17 minutes during which the well essentially killed itself, and a final shut-in of one hour. Figure 1 shows the pressure and rate history recorded during the DST. The well was completed in the top of the St Peter formation with the packer set at 3255 ft MD (bottom of sealing element) and a total depth of approximately 3300 ft MD. The top of the St Peters formation is estimated to be at 3170 ft but logs suggest that the entire open interval could have contributed to flow (although I am not an expert log analyst). Because there is uncertainty in the actual contributing interval, the analysis assumes the entire 45 feet were contributing to flow. Analyses were conducted using productive intervals from 30 to 110 feet to show the sensitivity of the model parameters (permeability, kv/kh and skin) to this uncertainty although the analysis based on the actual 45 foot interval is considered the most appropriate.

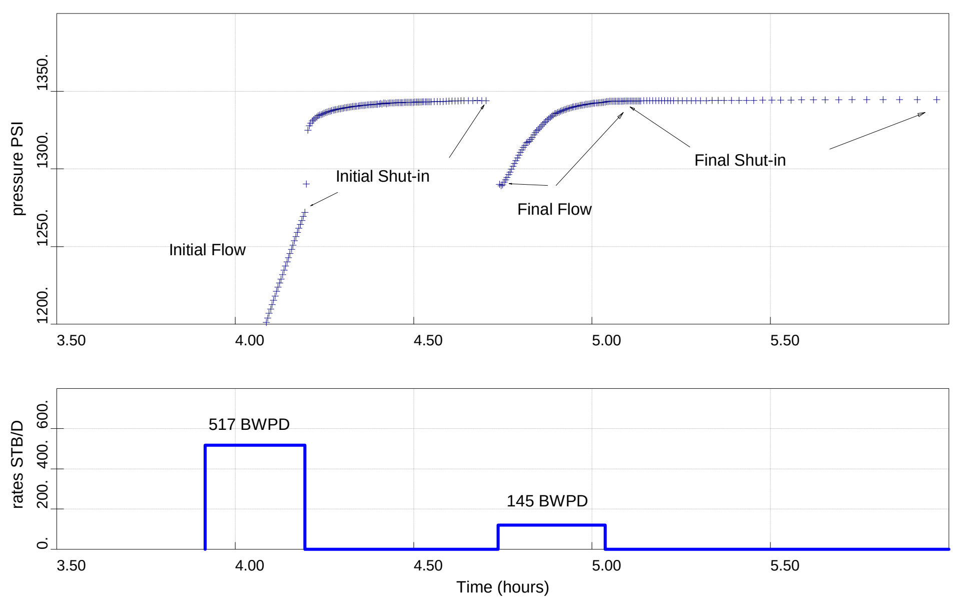


Figure 1 – Pressure and rate history of ADM CCS No.1 recorded during the March 6, 2009 DST of the interval 3270 – 3300 ft MD.

Analysis results are based on the initial shut-in period since it has a well defined shut-in as compared to the final shut-in. The test response shown in Figure 2 (the derivative plot) suggests a partial penetration model, which is appropriate since the St. Peter formation is approximately 200 feet thick and only the upper 45 feet were open to flow. The data are quite noisy near the end of the buildup (The downward trend in the derivative is characteristic of a limited entry (partial penetration) completion. The response in Figure 2 is shown compared to the partial penetration model summarized in Table 1 in order to emphasize the downward turn.

Figure 3 is an expanded pressure plot showing the undulations in the pressure during the shut-in periods. The initial shut-in contains reasonably good data with two questionable regions. There is a pressure shift about 13.5 minutes after shut-in and an upward swing about 11 minutes later. This last ten minutes of the initial buildup cannot be match with a diffusion model (pressure transient theory) and is excluded from the data used in my analysis. The final shut-in is seen to have significant pressure shifts and upward curvature which are indicative of wellbore or mechanical problems during the period. The partial penetration model summarized in Table 1 is plotted as the red line on Figure 3 and matches the overall pressure response of both shut-in periods quite well. The derivative plot is very sensitive to these shift and pressure variations thus the final shut-in derivative cannot be used for analysis. The pressure match obtained from the initial shut-in analysis is well within the uncertainties indicated by the observed variations in the data.

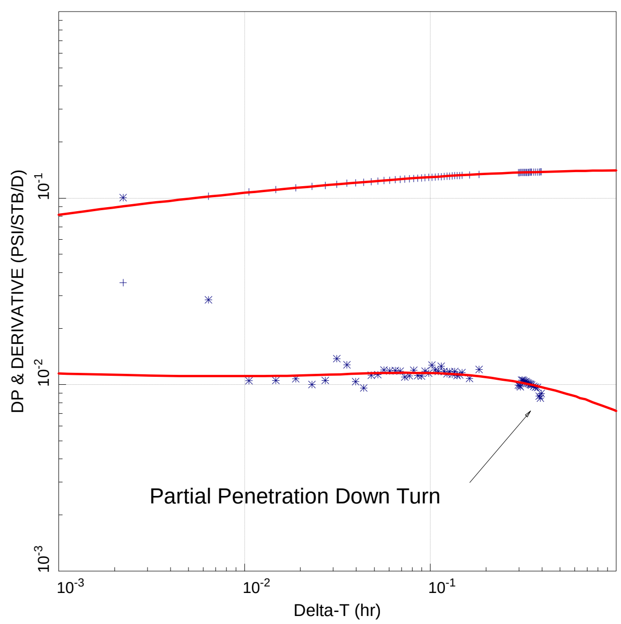


Figure 2 – The derivative response of the initial buildup recorded during DST-1 of ADM CCS No. 1 March 6, 2009. Data are compared to the model predictions of the partial penetration model summarized in Table 1.

Table 1 – Summary of the analysis results of DST-1 based on the partial penetration model assuming 45 ft of producing interval located at the top of the St. Peters formation

Property	**Initial Shut-in**
Permeability (md)	100.3
k_v/k_h	0.1
Permeability-Thickness (md-ft) based on 200 ft of net pay	20061
Completion interval (ft)	45
Total Formation Thickness (ft)	200
Distance of Center of open interval to the top of the formation (ft)	23
Skin	0.6
Wellbore Storage (RB/psi)	1×10^{-5}
Formation Pressure (psig)	1345.4
Depth of Pressure Gauge (ft MD)	3294

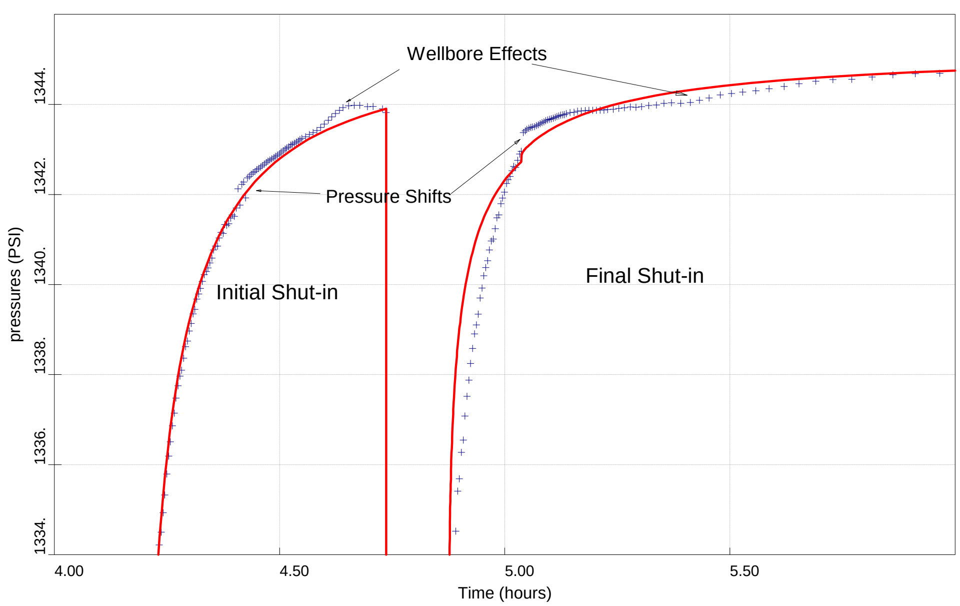


Figure 3 – Expanded pressure plot showing the variations in pressure during the initial and final shut-ins. Upward curvature indicates wellbore effects or mechanical problems and cannot be explained by pressure transient theory.

Analysis

During the second flow period the well essentially killed itself as it loaded up with water. When this happens it is difficult to pick the exact point of shut-in and the difference between the final flowing pressure and the shut-in pressures are very small. The uncertainty in shut-in time along with the variations in pressure shown in the final shut-in (Figure 3) cause significantly more noise in the data during the final shut-in. This is evident from the comparison of the derivatives of the initial and final shut-ins in Figure 4. The derivative of the initial buildup is very well behaved compared to the scatter observed in the final shut-in (Green points). For this reason the analysis is based on the initial shut-in. Data were further conditioned by removing areas where sudden pressure shifts occurred and when the first derivative increased.

Figure 2 shows the derivative of the initial buildup compared to the partial penetration model with 45 ft open to flow. The downward turn in the derivative is not well defined by the data but this feature is picked up by the optimizer in PIE, the pressure transient analyses software used in this analysis. Initial estimates of model parameters were made using straight line analysis of the derivative then these values were improved using the optimizer. The resulting parameters are summarized in Table 1. The partial penetration model is compared to the data in the superposition plot and the pressure history plot in Figures 5 and 6, respectively.

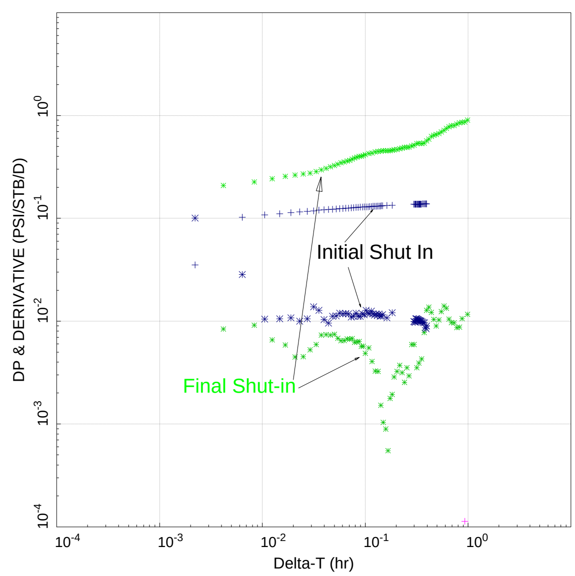


Figure 4 – Comparison of the derivatives of the initial and final shut-in periods of DST-1

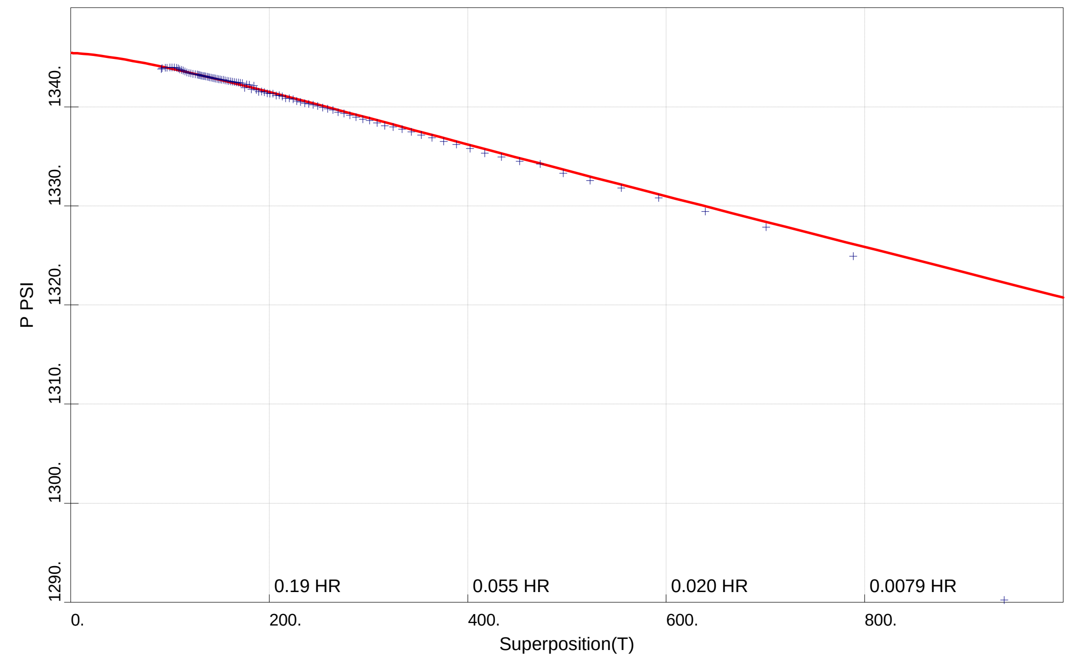


Figure 5 - Comparison of the predictions of the partial penetration model summarized in Table 1 compared to the superposition plot of the initial shut-in of DST-1

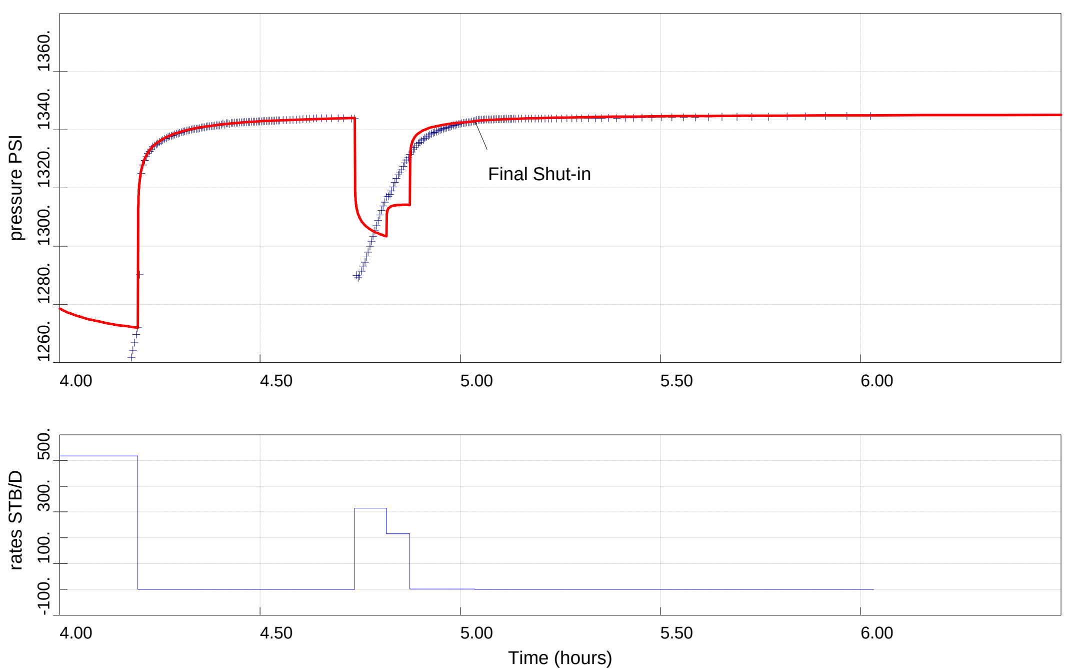


Figure 6 – Comparison of the partial penetration model summarized in Table 1 with the pressure history recorded during DST-1

Sensitivity Study

Since there is uncertainty in the interval contributing to flow during the DST, analyses were made assuming different intervals contributing to early radial flow as shown in Table 2. The 45 feet was the open hole under the packer. However, the estimated top of the St. Peter formation is 3270 ft MD (based on wire line measurements). Using these measurements the productive interval would be 30 feet. Depending on the vertical permeability a greater thickness could be contributing to the early radial flow regime. It is also possible that the drilling resulted in connection below the drilled interval (small fractures) or that the vertical permeability in the contributing layers is high. The interpretations for various effective flow intervals summarized in Table 2 provide an estimate of the uncertainty in the average permeability of the upper St Peter formation. Effective flow interval is defined in this context as the vertical interval which is contributing to the early radial flow regime in the partial penetration model. The entire 200 feet of St Peter formation in included in the model in each case. The intervals listed were provided to me by ISGS staff.

Matches to the data are essentially the same as those shown in Figures 3 – 6 for all of the cases. The appendix shows the derivative match for each of the cases listed in Table 2 along with the input parameters and results. Based on the results the average tested formation permeability ranges from 41.5 to 144 md with the most likely value being 100 md (the actual open interval below the packer). Vertical permeability ratios are reasonable for most of the cases but are seen to increase as the effective productive interval increases. Mechanical skin also increases with completion interval.

Table 2 – Comparison of results of varying the completion interval in the analysis of DST-1 of ADM CCS No.1. The 45 foot Open interval represents the measured open hole below the packer during the test.

Model Parameter	45 ft Open	30 ft Open	40 ft Open	60 ft Open	110 ft Open
Permeability (md)	**100.3**	144	110	75	41.5
k_v/k_h	**0.10**	0.04	0.1	0.3	1.4
Permeability-Thickness (md-ft) based on 200 ft of net pay	**20,061**	28,868	22,000	15,000	8,300
Completion interval (ft)	**45**	30	40	60	110
Distance of Center of open interval to the top of the formation (ft)	**23**	16	21	31	56
Skin	**0.6**	-0.4	0.4	0.7	1.1
Wellbore Storage (RB/psi)	**$1x10^{-5}$**	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$	$1x10^{-5}$
Formation Pressure (psig)	**1345.4**	1345.1	1345.1	1345.1	1345.3
Depth of Pressure Gauge (ft MD)	**3294**				

Conclusions

Analysis of the data recorded during DST-1 on ADM CCS No.1 results in the following conclusions:

- Data recorded during the initial buildup provided an analyzable response. This response was matched using the limited entry completion (partial penetration) model resulting in average formation permeability for the zone tested of 100 md. The skin and formation pressure determined by the test were 0.6 and 1345.4 psi respectively.
- The well was allowed to load up and kill itself during the final flow period which rendered the final buildup all but useless for pressure transient analysis. Impulse analysis was attempted but this method very seldom results in a satisfactory interpretation.
- Analyses performed with a number of open interval thicknesses resulted in very good matches to the data. These results place the permeability in the range of 41.5 md to 144 md with the most likely value of 100 md. Note that pressure transient analysis determines the transmissivity (kh/μ). Permeability is based on assumed values of thickness, h, and viscosity, μ, from other sources.

Recommendations

In future tests, especially when pressure transient analysis is an objective, it is recommended that the flow periods be conducted to avoid having the well kill itself.

It is also recommended that the service company provide a record of surface activity during the entire test. This should be provided even if no activities are being conducted.

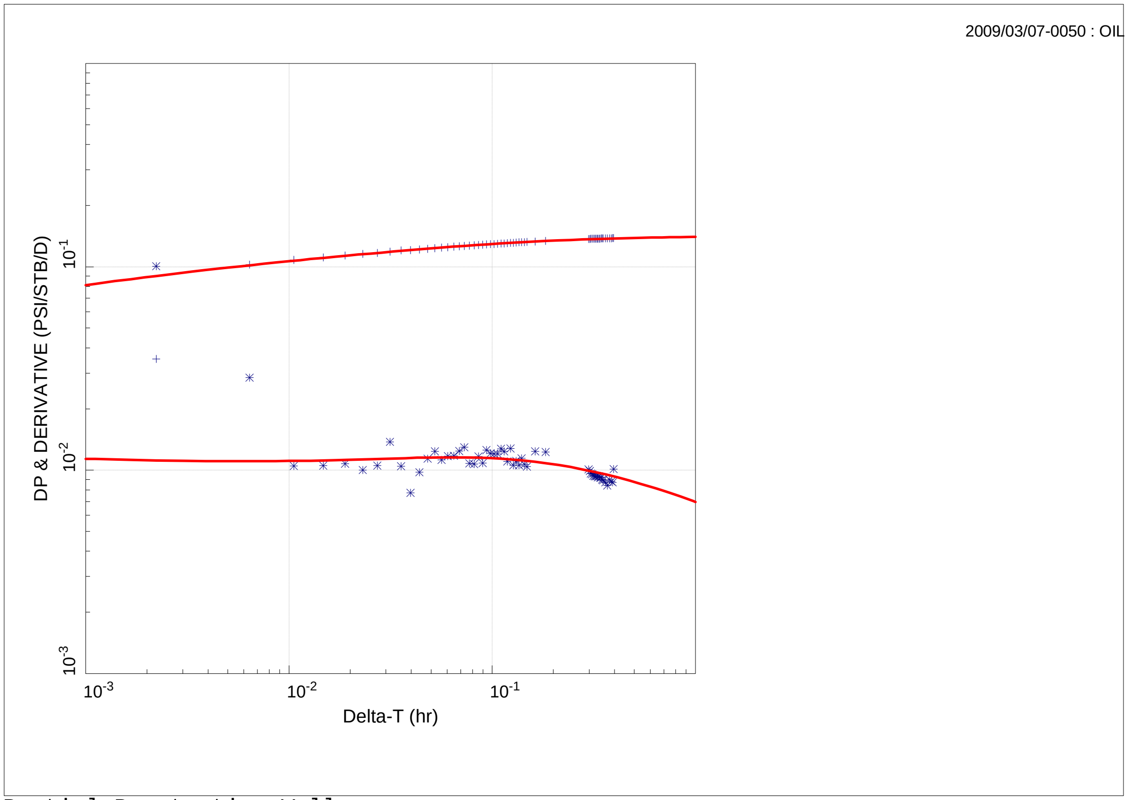
Disclaimer

The analyses presented here are based on the data provided by the client (oral and written) that may or may not be complete. Results are based on these data and the assumptions stated.

Analysis of pressure transients is an inverse problem which by its very nature is non-unique. Other interpretations may exists which provide acceptable matches to the recorded responses.

Appendix

Limited Entry Model with 45 Feet Open



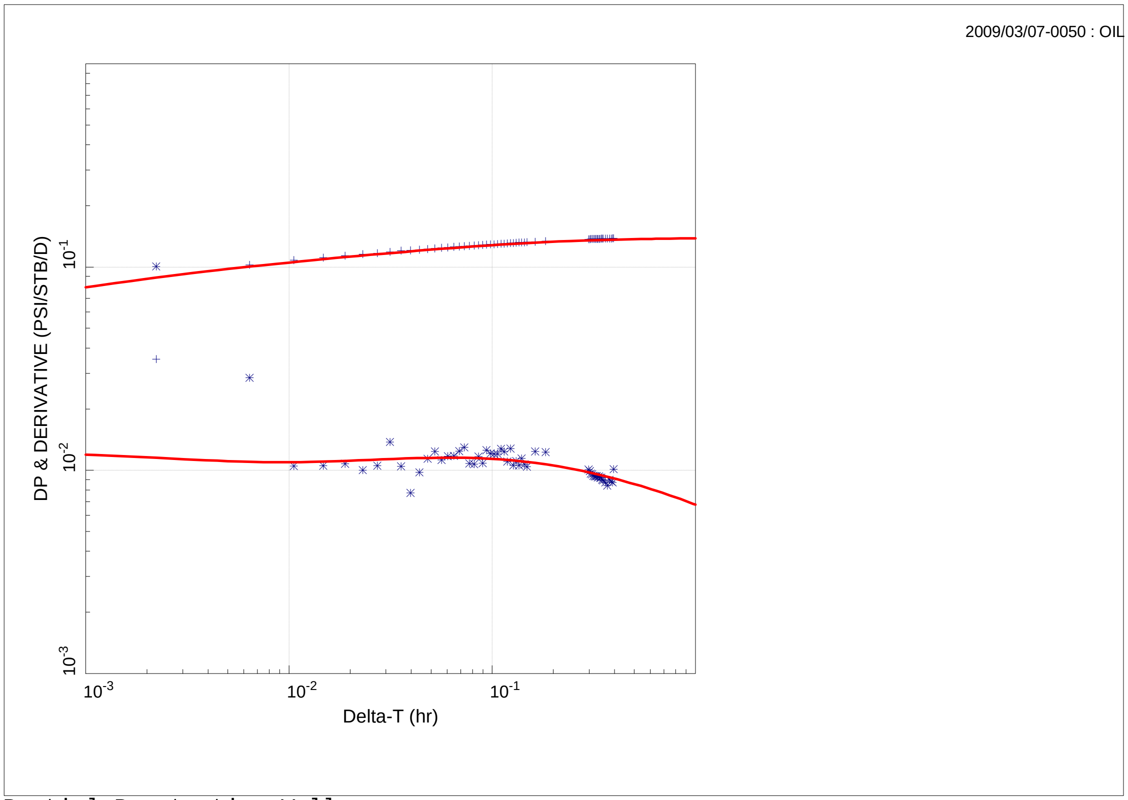
Partial Penetration Well
** Simulation Data **
well. storage = .7373E-05 BBLS/PSI
Skin(mech.) = 0.58857
permeability = 100.31 MD
Kv/Kh = 0.11733
Eff. Thickness = 200.00 FEET
Zp/Heff = 0.11500
Skin(Global) = 23.478
Perm-Thickness = 20061. MD-FEET
Initial Press. = 1345.17 PSI
Smoothing Coef = 0.020,0.

Type-Curve Model Static-Data
Perf. Interval = 45.0 FEET

Static-Data and Constants
Volume-Factor = 1.030 vol/vol
Thickness = 200.0 FEET
Viscosity = 0.7000 CP
Total Compress = .9270E-05 1/PSI
Rate = 517.0 STB/D
Storivity = 0.0003152 FEET/PSI
Diffusivity = 23980. FEET^2/HR
Gauge Depth = 3294. FEET
Perf. Depth = N/A FEET
Datum Depth = N/A FEET
Analysis-Data ID: GEC3
Based on Gauge ID: ALL
PFA Starts: 2009-03-07 00:34:30
PFA Ends : 2009-03-07 01:23:15

Figure A1 – Input parameters and analysis results for the limited entry model assuming 45 feet open to the well. Parameters listed under the plot are summarized in Table 1.

Limited Entry Model with 30 Feet Open



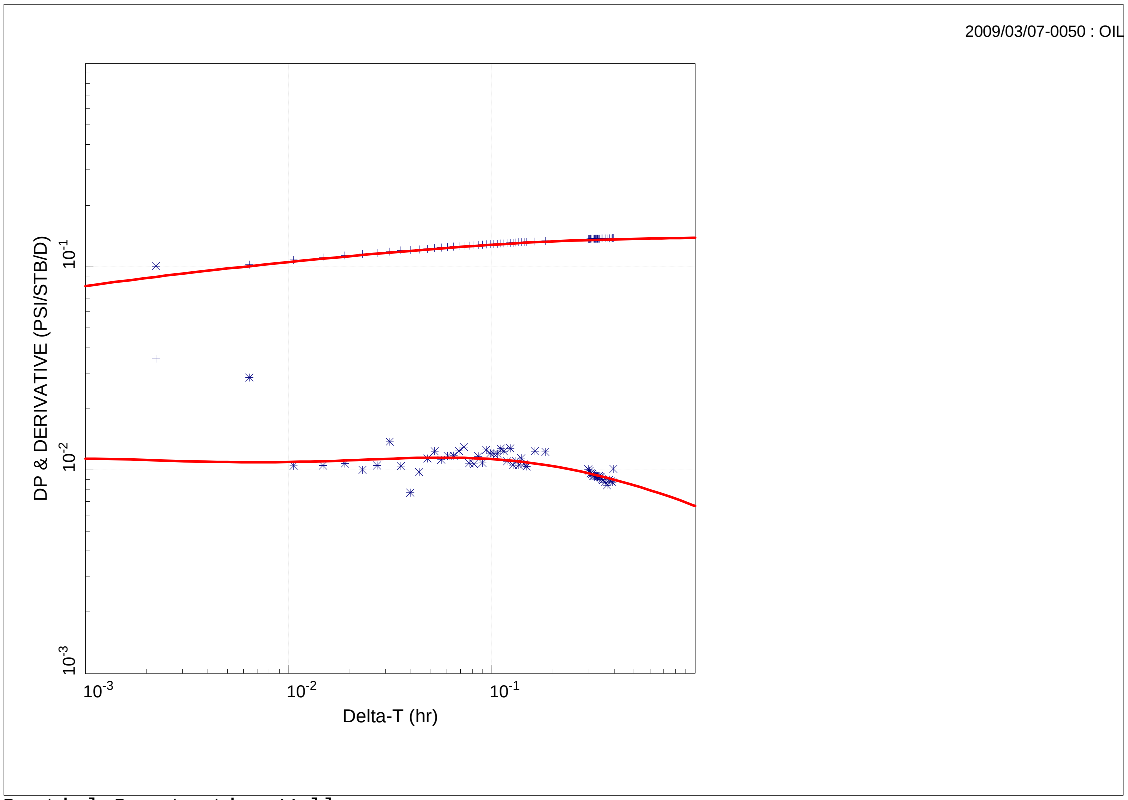

```
Partial Penetration Well
** Simulation Data **
 well. storage  = .1000E-04 BBLS/PSI
 Skin(mech.)    =   0.19309
 permeability   =    144.34 MD
 Kv/Kh          =  0.042344
 Eff. Thickness =    200.00 FEET
 Zp/Heff        =  0.080000
 Skin(Global)   =    36.242
 Perm-Thickness =    28868. MD-FEET
 Initial Press. =   1345.08 PSI
 Smoothing Coef = 0.020,0.
```

```
Type-Curve Model Static-Data
Perf. Interval = 30.0 FEET

Static-Data and Constants
Volume-Factor  = 1.030 vol/vol
Thickness      = 200.0 FEET
Viscosity      = 0.7000 CP
Total Compress = .9270E-05 1/PSI
Rate           = 517.0 STB/D
Storivity      = 0.0003152 FEET/PSI
Diffusivity    = 34500. FEET^2/HR
Gauge Depth    = 3294. FEET
Perf. Depth    = N/A FEET
Datum Depth    = N/A FEET
Analysis-Data  ID: GEC3
Based on Gauge ID: ALL
PFA Starts: 2009-03-07 00:34:30
PFA Ends  : 2009-03-07 01:23:15
```

Figure A2 – Input parameters and analysis results for the limited entry model assuming 30 feet open to the well. Parameters listed under the plot are summarized in Table 2.

Limited Entry Model with 40 Feet Open



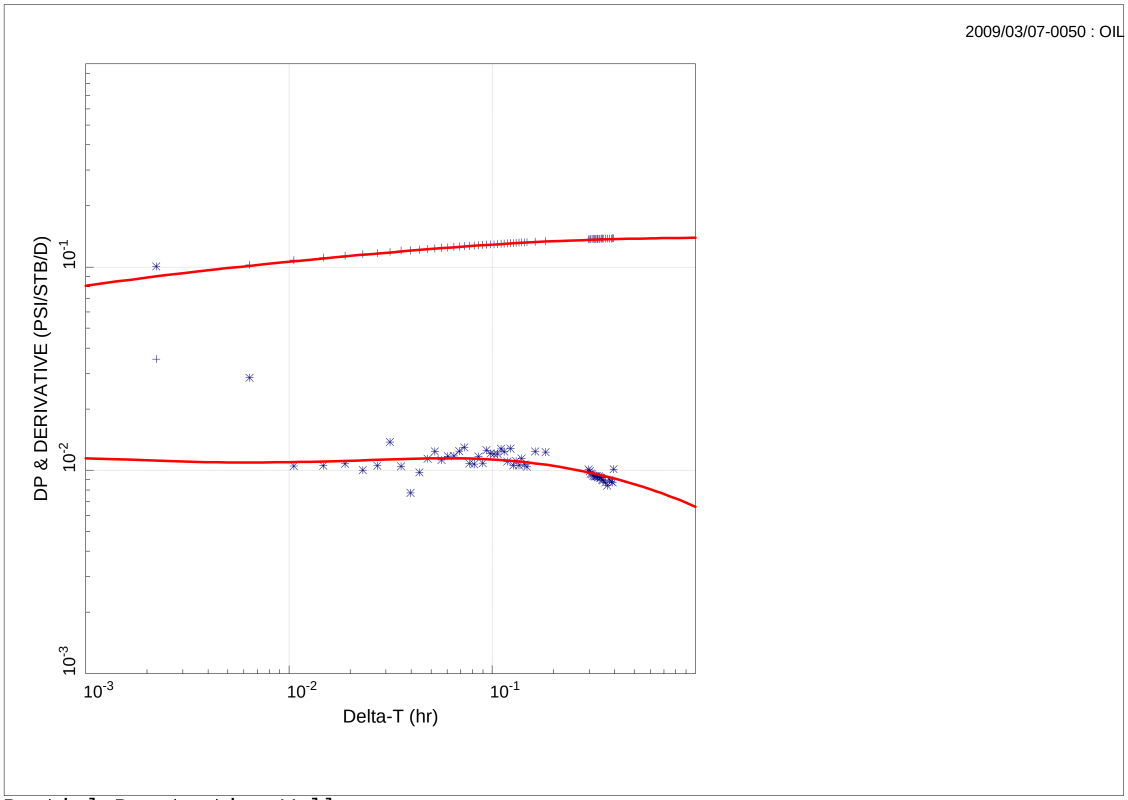

```
Partial Penetration Well
** Simulation Data **
 well. storage  = .1000E-05 BBLS/PSI
 Skin(mech.)    =   0.40000
 permeability   =    110.00 MD
 Kv/Kh          =  0.099975
 Eff. Thickness =    200.00 FEET
 Zp/Heff        =   0.10500
 Skin(Global)   =    25.913
 Perm-Thickness =    22000. MD-FEET
 Initial Press. =   1345.10 PSI
 Smoothing Coef = 0.020,0.
```

```
Type-Curve Model Static-Data
Perf. Interval = 40.0 FEET

Static-Data and Constants
Volume-Factor  = 1.030 vol/vol
Thickness      = 200.0 FEET
Viscosity      = 0.7000 CP
Total Compress = .9270E-05 1/PSI
Rate           = 517.0 STB/D
Storivity      = 0.0003152 FEET/PSI
Diffusivity    = 26300. FEET^2/HR
Gauge Depth    = 3294. FEET
Perf. Depth    = N/A FEET
Datum Depth    = N/A FEET
Analysis-Data  ID: GEC3
Based on Gauge ID: ALL
PFA Starts: 2009-03-07 00:34:30
PFA Ends  : 2009-03-07 01:23:15
```

Figure A3 – Input parameters and analysis results for the limited entry model assuming 40 feet open to the well. Parameters listed under the plot are summarized in Table 2.

Limited Entry Model with 60 Feet Open



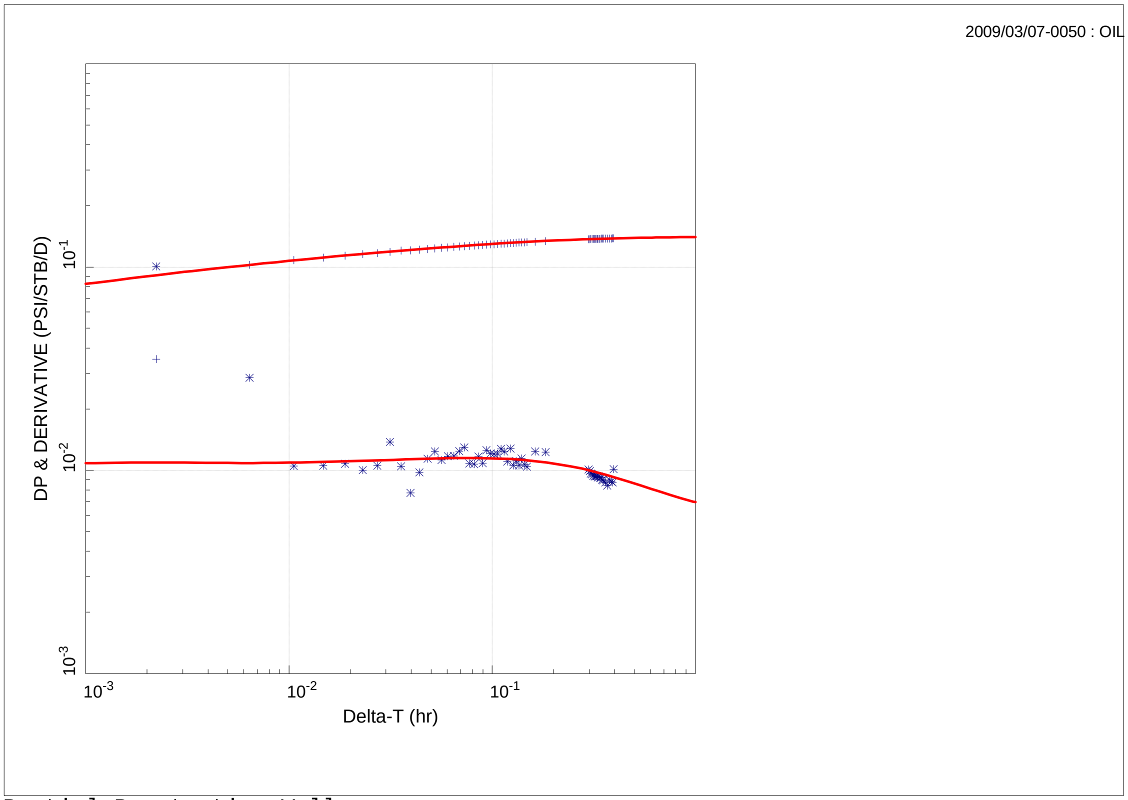

```
Partial Penetration Well
** Simulation Data **
 well. storage  = .1000E-04 BBLS/PSI
 Skin(mech.)    =   0.71010
 permeability   =    75.000 MD
 Kv/Kh          =   0.30000
 Eff. Thickness =    200.00 FEET
 Zp/Heff        =   0.15500
 Skin(Global)   =    15.742
 Perm-Thickness =    15000. MD-FEET
 Initial Press. =   1345.10 PSI
 Smoothing Coef = 0.020,0.
```

```
Type-Curve Model Static-Data
Perf. Interval = 60.0 FEET

Static-Data and Constants
Volume-Factor  = 1.030 vol/vol
Thickness      = 200.0 FEET
Viscosity      = 0.7000 CP
Total Compress = .9270E-05 1/PSI
Rate           = 517.0 STB/D
Storivity      = 0.0003152 FEET/PSI
Diffusivity    = 17930. FEET^2/HR
Gauge Depth    = 3294. FEET
Perf. Depth    = N/A FEET
Datum Depth    = N/A FEET
Analysis-Data  ID: GEC3
Based on Gauge ID: ALL
PFA Starts: 2009-03-07 00:34:30
PFA Ends  : 2009-03-07 01:23:15
```

Figure A4 – Input parameters and analysis results for the limited entry model assuming 60 feet open to the well. Parameters listed under the plot are summarized in Table 2.

Limited Entry Model with 110 Feet Open




```
Partial Penetration Well
** Simulation Data **
 well. storage  = .1000E-05 BBLS/PSI
 Skin(mech.)    =    1.1000
 permeability   =    41.500 MD
 Kv/Kh          =    1.4000
 Eff. Thickness =    200.00 FEET
 Zp/Heff        =   0.28000
 Skin(Global)   =    6.3398
 Perm-Thickness =    8300.0 MD-FEET
 Initial Press. =   1345.34 PSI
 Smoothing Coef = 0.020,0.
```

```
Type-Curve Model Static-Data
Perf. Interval = 110. FEET

Static-Data and Constants
Volume-Factor  = 1.030 vol/vol
Thickness      = 200.0 FEET
Viscosity      = 0.7000 CP
Total Compress = .9270E-05 1/PSI
Rate           = 517.0 STB/D
Storivity      = 0.0003152 FEET/PSI
Diffusivity    = 9920. FEET^2/HR
Gauge Depth    = 3294. FEET
Perf. Depth    = N/A FEET
Datum Depth    = N/A FEET
Analysis-Data  ID: GEC3
Based on Gauge ID: ALL
PFA Starts: 2009-03-07 00:34:30
PFA Ends  : 2009-03-07 01:23:15
```

Figure A5 – Input parameters and analysis results for the limited entry model assuming 110 feet open to the well. Parameters listed under the plot are summarized in Table 2.

Interpretation of Wireline Log Data in the St. Peter Sandstone
ADM Company – CCS Well #1

Prepared by Robert J. Butsch, Schlumberger Carbon Services, Sugar Land, TX
Edited by Edward Mehnert, Illinois State Geological Survey, Champaign, IL

Summary

Openhole wireline logs were run in the ADM CCS #1 well in Decatur, Macon County, Illinois. One of the primary purposes of the logs was to determine the salinity of the water in the St. Peter Sandstone.

Based on the analysis of the wireline logs, the salinity of the water in the St. Peter Sandstone appears to be increasing with depth from about 7,900 mg/L NaCl (equivalent) at the top of the formation to about 12,600 mg/L NaCl (equivalent) at the bottom of the formation. The change in salinity in the formation is likely due to gravity segregation with the denser, higher salinity water settling to the bottom of the formation. The formation and fluid properties resulting from the analysis over selected intervals within the St. Peter are listed in Table 1, as well as average values calculated for the entire zone which is 202 feet thick. Figure 1 is a graphical view of this analysis.

Table 1. Summary of salinity calculations for the St. Peter fluids from CCS #1

Formation	Top (ft)	Bottom (ft)	Thickness (ft)	Av Phi (--)	Av Vcl (--)	Av Sal2 (mg/L)	Av Sal185 (mg/L)
St. Peter top	3268	3278	10.5	0.206	0.144	10,239	7,947
St. Peter middle	3278	3382	103.5	0.209	0.067	13,796	10,701
St. Peter lower	3382	3470	88.0	0.168	0.059	16,856	12,598
Thickness weighted average						14,944	11,384
Pore volume weighted average						14,769	11,274

Notes:
1) Top and Bottom depths are given with respect to the Kelly Block, which was set at elevation 689.85 ft. The ground elevation was 674.22 ft.
2) Abbreviations used: Av Phi – Average porosity, Av Vcl – Average volume of shale, Av Sal2 – Average salinity using m=2.0, Av Sal185 – Average salinity using m=1.85
3) Thickness weighted average= Σ(thickness*salinity)/ Σ thickness
4) Pore volume weighted average= Σ(thickness*porosity*salinity)/ Σ(thickness*porosity)

The Logging Program

The logging program consisted of a single run of the Platform Express (PEX). These logs were run March 9, 2009 in an open borehole (i.e., no casing in the borehole). The PEX is actually a combination of several tools that make up what is commonly referred to as a Triple Combo. The three main tools that are contained in this logging tool combination are the resistivity, the density, and the neutron tools. Several other tools and measurements are also included in the normal tool string and Table 2 lists the tools (measurements) and their common use in the analysis. A brief explanation of the various logs appears in Figure 1 and 2.

Table 2. Logging Tools Run

Logging Run	Logging tools	Data Used For:
PEX (Platform Express)	GR – Gamma Ray	Correlation and Volume of Shale
	SP – Spontaneous Potential	Correlation and Volume of Shale
	Caliper	Hole size
	Resistivity	Correlation, Saturations / Salinity
	Density	Density Porosity, Fluid Type
	Neutron	Neutron Porosity, Fluid Type

Interpretation of the data

The interpretation of the data was based on the Archie formula and the following steps were taken:

1. Data QC to verify all data are good and on depth with all other data.
2. Compute volume of shale using GR, SP, and Density/Neutron cross plot.
3. Compute porosity using Density/Neutron cross plot
4. Use Pickett plot to select value for "m" in Archie formula.
5. Compute Apparent Water Resistivity (Rwa) using Archie formula assuming formation contains all water or Sw=100%
6. Compute salinity NaCl (equivalent) from the resulting Rw.

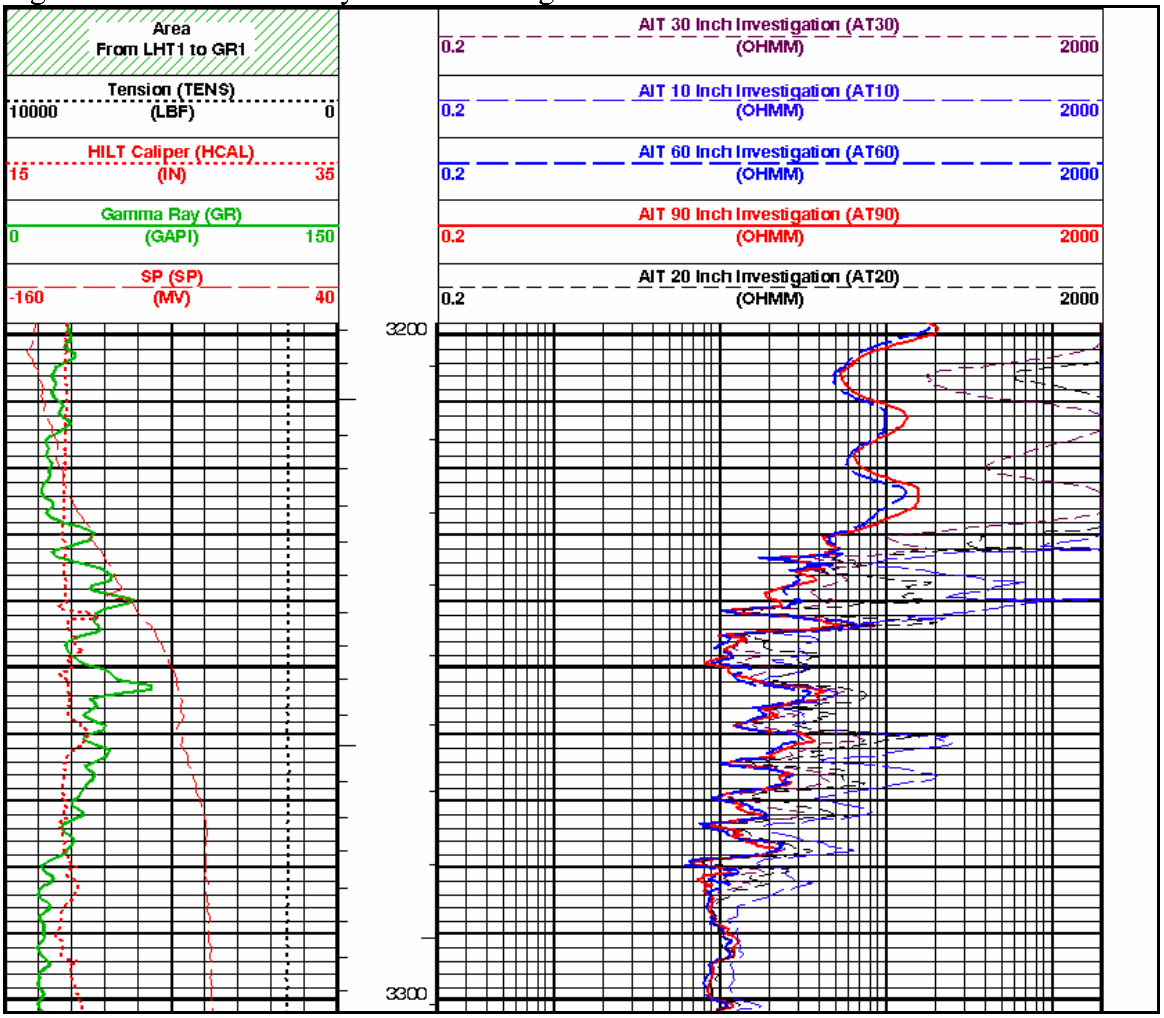
The Archie formula is the oldest and most widely used equation for solving log data for water saturation. The formula is:

$$Sw^n = (a * R_w) / (\Phi^m * R_t)$$

Where:
Sw = Water Saturation
n = Saturation Exponent (normally = 2.0)
a = empirically derived correction factor (normally = 1.0)
R_w = Resistivity of the water
Φ = Porosity
m = Cementation factor (normally = 2.0)
R_t = True Resistivity of the un-invaded formation

For this analysis rather than using the equation and measurements to solve for water saturation, the water saturation will be assumed to be 100%. The equation can then be used to solve for the resistivity of the water which is usually an input parameter. The parameters "a" and "n" can have some affect on the analysis but in many cases the amount of change is not significant, and these parameters are difficult to measure. The default values of 1 and 2 will be used respectively for these parameters. The value of "m" is easier to determine as this can be done by the use of the Pickett plot. The Pickett plot is a cross plot of porosity versus resistivity and can be used for determining the average value of R_w in a zone as well as "m". "m" is determined by the slope of the line that can be drawn through the highest frequency of data points in a water bearing formation. Figures 4 and 5 are Pickett plots of the St. Peter Sandstone with lines that represent different "m" values. Figure 4 has an "m" of 2.0 and Figure 5 has an "m" of 1.85. The value of m=1.85 was selected as the most appropriate value for this formation, but the results using a "m" value of 2.0 are also presented since this is the most commonly used value in sandstone. It can

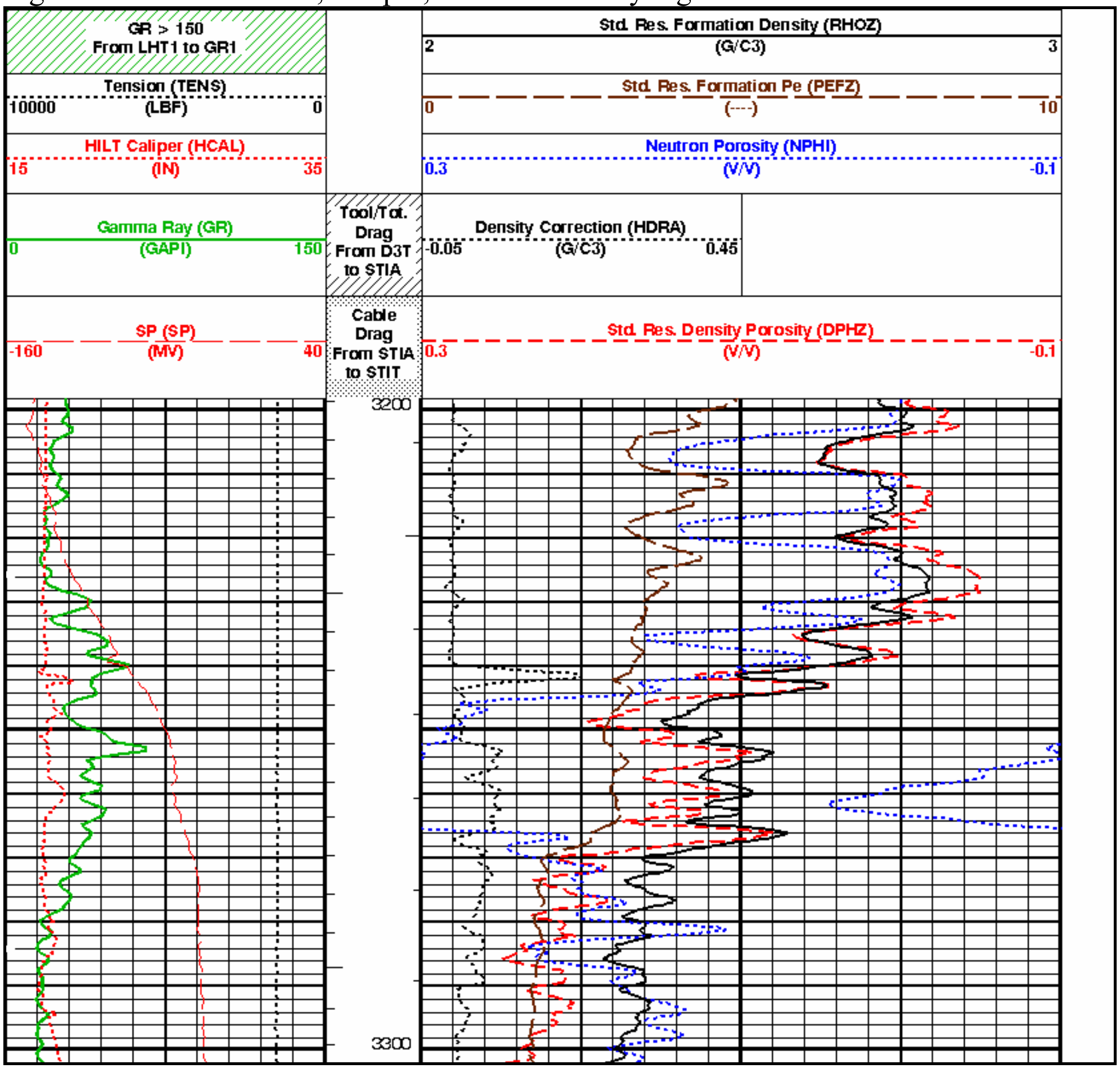
Figure 1. PEX – Resistivity and related logs



Track 1 (left side)
Tension – Tension on the cable while logging. This can indicate pick-up or pulls where tool stops.
SP (Spontaneous Potential) – Can be used as an indicator of sand/shale.
Caliper – A measurement of the borehole size on one axis.
Gamma Ray – Measurement of naturally occurring gamma rays. An indicator of sand/shale.

Tracks 2 & 3 (right side)
AIT Mud – Resistivity of the drilling mud.
AIT90 – Array Induction measurement with 90 inch radial depth of investigation.
AIT60 – Array Induction measurement with 60 inch radial depth of investigation.
AIT30 – Array Induction measurement with 30 inch radial depth of investigation.
AIT20 – Array Induction measurement with 20 inch radial depth of investigation.
AIT10 – Array Induction measurement with 10 inch radial depth of investigation.

Figure 2. PEX – Nuclear, Caliper, and Gamma Ray logs



<u>Track 1 (left side)</u>

Tension – Tension on the cable while logging. This can indicate pick-up or pulls where tool stops.

SP (Spontaneous Potential) – Can be used as an indicator of sand/shale.

Caliper – A measurement of the borehole size on one axis.

Gamma Ray – Measurement of naturally occurring gamma rays. An indicator of sand/shale.

<u>Tracks 2 & 3 (right side)</u>

PEFZ – Photoelectric Effect. This is used for lithology identification.

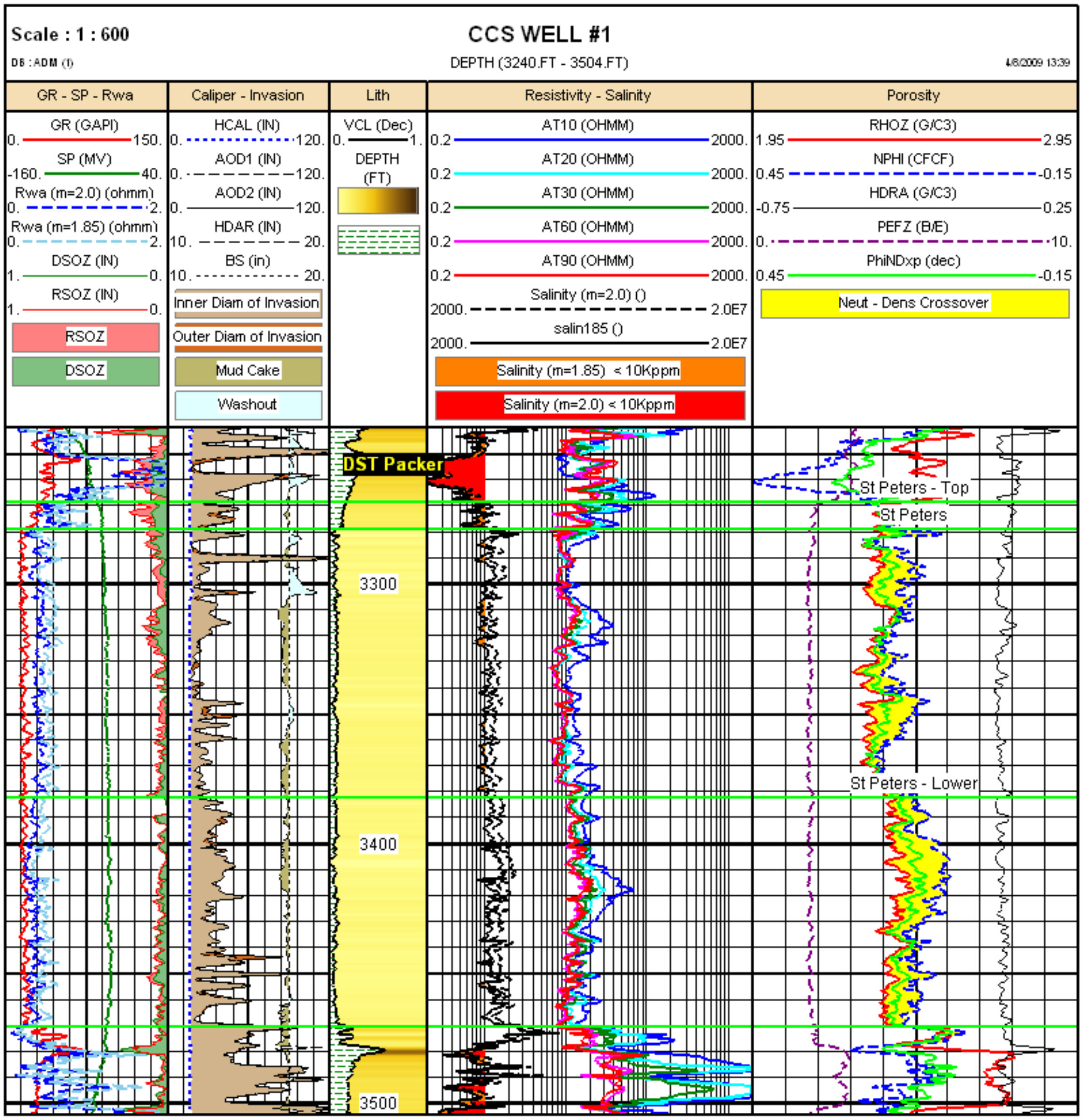
RHOZ – Measurement of the bulk density of the formation. This is used in combination with the neutron and sonic for lithology identification as well as identification of fluids in the porosity.

NPHI - Measurement of the neutron porosity of the formation. This is used in combination with the density and sonic for lithology identification as well as identification of fluids in the porosity.

HDRA – This is the correction that has been applied to the density measurement to account for things like mudcake. This is used as a quality control indicator for the density measurement.

DPHZ – This is the porosity calculated using the bulk density measurement assuming the porosity is water-filled.

Figure 3. Salinity Analysis of the St. Peter Sandstone



Track 1 – GR-SP-Rwa (left side)
Gamma Ray – Measurement of naturally occurring gamma rays. An indicator of sand/shale
SP (Spontaneous Potential) – Can be used as an indicator of sand/shale.
RSOZ – Resistivity Standoff, Quality control indicating enlarged borehole.
DSOZ – Density Standoff, Quality control indicating enlarged borehole.
Rwa (m=2.0) – Apparent water resistivity using an m value of 2.0 in the Archie equation.
Rwa (m=1.85) – Apparent water resistivity using an m value of 1.85 in the Archie equation.

Track 2 – Caliper-Invasion (left center)
HCAL – Caliper measurement, shows hole size
HDAR – Hole Diameter measurement, shows hole size
BS – Bit Size
AOD1 – Calculated Inner Diameter of Invasion
AOD2 - Calculated Inner Diameter of Invasion

Track 3 – Lithology (center)
VCL – Indicates total volume of clay and volume of sand (no porosity)

Depth – Measured Depth

Track 4 – Resistivity – Salinity (right center)
AIT10 – Array Induction measurement with 10 inch radial depth of investigation.
AIT20 – Array Induction measurement with 20 inch radial depth of investigation.
AIT30 – Array Induction measurement with 30 inch radial depth of investigation.
AIT60 – Array Induction measurement with 60 inch radial depth of investigation.
AIT90 – Array Induction measurement with 90 inch radial depth of investigation.
Salinity (m=2.0) – Salinity calculated from Rwa using m=2.0 in Archie equation.
Salinity185 – Salinity calculated from Rwa using m=1.85 in Archie equation.

Track 4 – Porosity (right)
PEFZ – Photoelectric Effect. This is used for lithology identification.
RHOZ – Measurement of the bulk density of the formation. This is used in combination with the neutron and sonic for lithology identification as well as identification of fluids in the porosity.
NPHI - Measurement of the neutron porosity of the formation. This is used in combination with the density and sonic for lithology identification as well as identification of fluids in the porosity.
HDRA – This is the correction that has been applied to the density measurement to account for things like mudcake. This is used as a quality control indicator for the density measurement.
PhiNDxp – Calculated "Cross plot" porosity using Density and Neutron measurements.

be noted that using the "m" value of 2.0 increases the salinity. The continuous outputs of salinity can be seen on the log and the average values over the selected intervals can be seen in Table 1. In Table 1, the Av Sal2 is the values with m= 2.0 and the Av Sal185 is the values with m= 1.85.

Figures 4 and 5 were made using data from the entire interval of the St. Peter and are presented as frequency plots. To understand the relationship between "m" and Rw in the three intervals that have been identified within the St. Peter, Pickett plots have been made for each of the intervals and are presented as Figures 6, 7, and 8. When comparing the Pickett plots of the three intervals within the St. Peter, the slope of the data remains constant yet the points within a section plot differently relative to the plotted line that was derived using all points. As the points move down and to the left, this would indicate that the salinity is increasing. As the points move up and to the right as in Figure 8, this would indicate that the salinity of the water is decreasing.

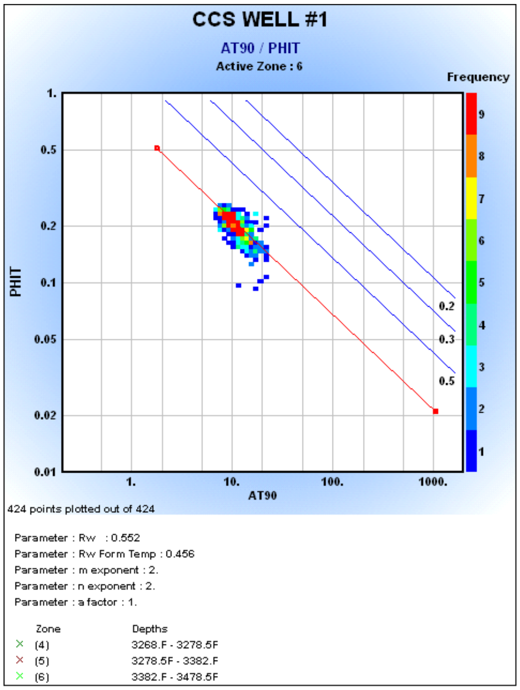


Figure 4. Pickett plot, m=2

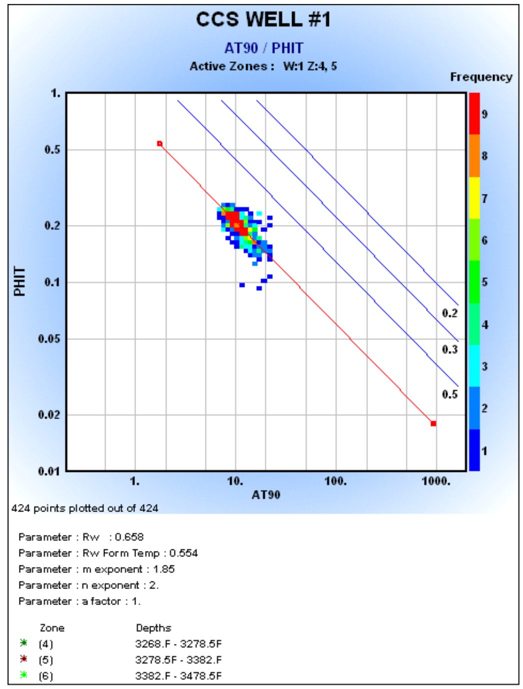


Figure 5. Pickett plot, m=1.85

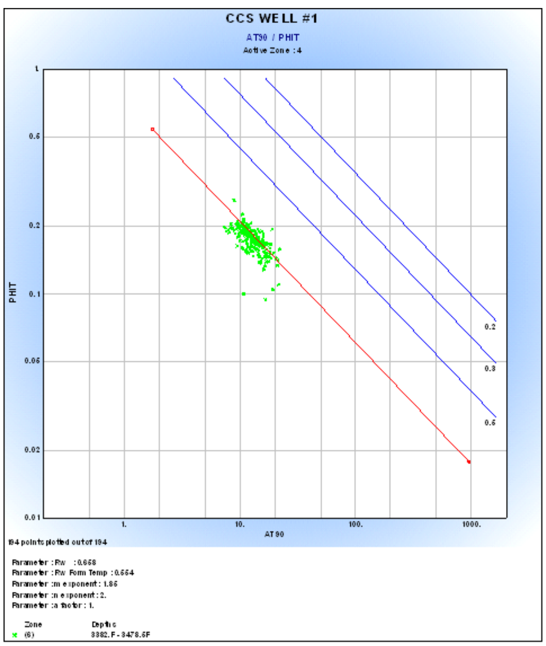


Figure 6. Pickett plot of St. Peter (bottom)

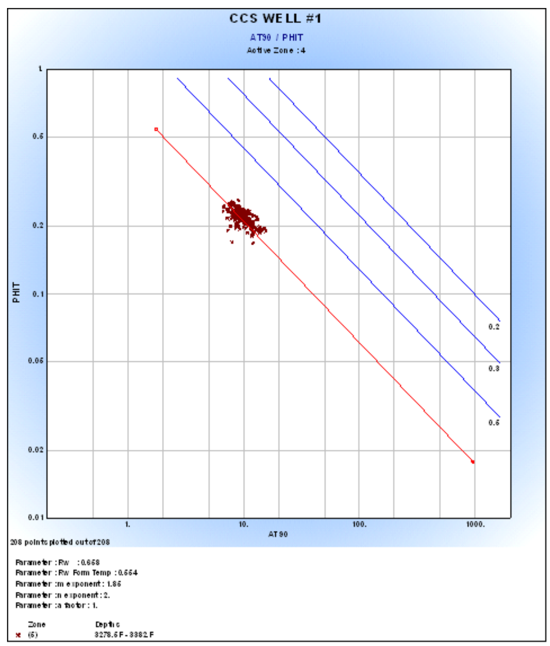


Figure 7. Pickett plot of St. Peter (middle)

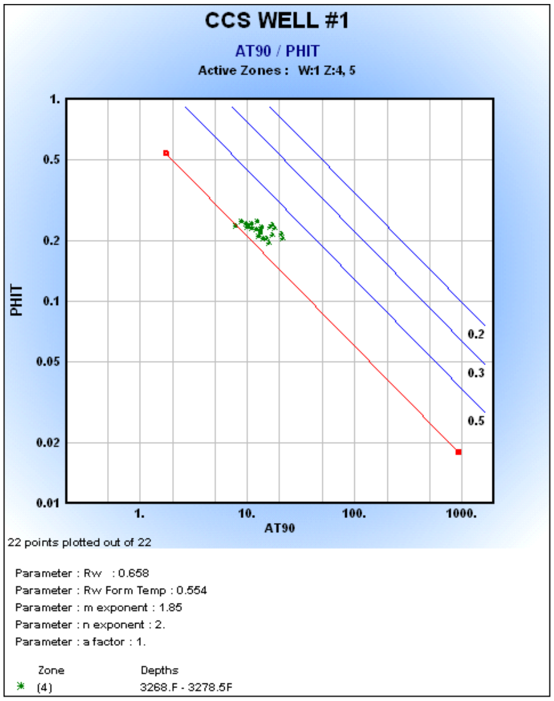


Figure 8. Pickett plot of St. Peter (top)

Testing of the Pennsylvanian Bedrock

E. Mehnert, S. Frailey, A. Iranmanesh, Ivan G. Krapac, T.C. Young, ISGS Draft: 6/23/09

Introduction

Per its Underground Injection Control Class I permit with Illinois Environmental Protection Agency, ADM is required to monitor the lowermost underground source of drinking water (USDW). A USDW is defined based on its hydraulic conductivity (K> $1x10^{-4}$ cm/sec) and its water quality (total dissolved solids <10,000 mg/L). At the time that the permit was issued, the available data indicated that the lowermost USDW would be found in the St. Peter Sandstone or at a depth greater than 200 feet and less than 800 feet beneath the ADM facility. The 200 foot depth was determined by water sampling in MMV-01, which is approximately 100 feet north of the injection well. The 800-foot depth was determined from analysis of resistivity logs by Illinois State Geological Survey (ISGS) scientists for wells approximately 5 miles west of the ADM facility. The bedrock beneath the ADM facility, at depths exceeding 800 feet, is Pennsylvanian-age bedrock.

To locate the lowermost USDW within the Pennsylvanian bedrock, the ISGS collected core of the Pennsylvanian bedrock and ran a number of tests. Packer testing was conducted to determine in situ hydraulic conductivity. Geophysical logs were run to determine the rock and pore fluid properties and included natural gamma, SP, single point resistivity (SPR), resistivity (8", 16 ", 32" & 64") and fluid temperature/resistivity. In addition, fluid samples were collected using a discrete interval sampler, which is a stainless steel tool that allows borehole fluid to flow into an air-filled chamber at the desired depth. The results for the coring, geophysical logging, and fluid sampling are summarized below.

Drilling and Coring Operations

The corehole was named MMV-04B (API= 121152339600) and is located in Macon Co., Sec 32 T17N R3E. This site is located approximately 200 feet SE of the intersection of Brush College Rd. and Rea's Bridge Rd. in Decatur and approximately 1,850 northwest of ADM CCS#1 (injection well). Ground surface elevation of the drilling site is approximately 681 ft above MSL.

Materials in this borehole were not sampled to a depth of 148 ft, but the bedrock surface was found at an approximate depth of 120 feet (±5 feet). Albrecht Well Drilling (Ohio, IL) was hired to drill through the Quaternary sediments and into the upper bedrock. The borehole was drilled using an Ingersoll-Rand TH-60 drill rig equipped with a 10-inch tri-cone roller bit. This mud rotary rig used a bentonite based mud for this portion of the project. Albrecht installed 6 inch, steel casing from the ground surface to 148 feet below ground surface. This casing was cemented with neat cement slurry using the Halliburton method. The cement was supplied by Grohne Concrete (Decatur, IL). All water used for drilling and coring was supplied by ADM. This portion of the project was conducted from February 16 through February 19, 2009.

Beginning at a depth of 148 ft, HQ-sized core (2.5 inch outside diameter) was collected by a CME-75 coring rig and a wireline coring system owned and operated by Raimonde Drilling Corporation (Addison, IL). The coring system used diamond bits and water as the drilling fluid. The core barrel was spun at a high rate, approximately 800 revolutions per minute. Wireline coring was used to collect core to a depth of 504 feet. Core recovery from this borehole was excellent, with RQD (Rock Quality Designation) generally greater than 95%. This portion of the project was conducted from February 23 through February 28, 2009. The bedrock materials recovered from this borehole are described in Table 1.

Table 1. Brief Geologic Log for MMV-04B (Macon Co., Sec 32 T17N R3E, API = 121152339600)

Depth (ft)	Description
0-148	Not sampled
148-165	Shale, gray with thin siltstone and sandstone (156.75-156.95 ft) layers
165-171	Limestone, gray, fossiliferous, with shale layer (169.7-170.1)
171-183	Shale, gray and black (171.8-174.0)
183-224	Siltstone with shale and sandstone (184.0-184.2, 214.0-214.2) interbedded
224-229	Shale, gray and brown
229-244	Limestone, greenish gray, some weathering?
244-250	Siltstone, shaley
250-257	Carbonate (LS or dolomite)
257-259	Shale, black, organic rich & oily (256.8-259.2)
259-263	Carbonate, gray, fossiliferous, fractured
263-266	Siltstone, laminated, softened by drilling
266-299	Sandstone, fine grained, slickensided face at 272, 275.4, 45 deg fracture at 296.2-296.6, laminated, horizontal and some deformed beds
299-303	Interbedded sandstone and siltstone, light to dark, greenish gray
303-304	Shale, black (0.9 ft) and coal (0.4 ft)
304-309	Shale, dark gray, laminated, heavy fossil concentration at 309.1-310
309-324	Limestone, dark greenish gray, slickensided fracs noted at 311.4, 312.0, 312.6, 315.0, core cut rough 314-317.5
324-330	Siltstone to shale (finer grained at bottom), reddish brown to greenish gray
330-359	Interbeds of gray shale and limestone
359-374	Limestone with shale (green to black) at 367.8-369.8 Carthage/Shoal Creek LS?
374-382	Interbedded shale, limestone & shale
382-383	Sandstone, very fine grained, beige to greenish gray Inglefield Sandstone?
383-390	Siltstone
390-405	Sandstone with siltstone interbeds, fine grained Trivoli Sandstone?
405-414	Siltstone with shale interbeds
414-424	Shale, gray
424-425	Coal
425-440	Shale with siltstone interbeds
440-459	Limestone with black shale at 449.8-450.1 West Franklin LS?
459-460	Shale, black & gray
460-504	Siltstone, greenish gray, vertical fractures at 488-489 & 493-494 (slickensided) Farmington Shale?

Upon completion of coring, the borehole was backfilled to a depth of 295 feet using gravel pack and bentonite pellets. This backfill was designed to hydraulically seal the monitored interval from groundwater in deeper sediments and to provide a stable base to build the well. For reasons to be explained below, a bentonite plug was set at a depth of 295 to 325 feet, while intervals of gravel pack and bentonite chips were used to backfill deeper portions of the borehole. After backfilling, the borehole was reamed by Albrecht using the mud and air rotary methods. A 6-inch diameter, tri-cone roller type TCI (tungsten carbide insert) bit was used, while water was utilized as the drilling fluid. Because borehole stability was an issue, the borehole was also cleaned out using air rotary drilling with foam drilling fluid. After the borehole was completed, the monitoring well was constructed. See the **Monitoring Well Design** section for additional details. This portion of the project was conducted from March 5 through March 13, 2009.

The monitoring well was developed using a bailer from March 17 and 19 and May 12, 2009.

Geophysics/Borehole Logging

For borehole logging, the ISGS uses an MGXII data acquisition system manufactured by the Mount Sopris Instrument Company (MSI, Golden, CO). The wireline winch is a Mount Sopris, 4WNA-1000 model capable of holding 1,800 meters (or 5,900 feet) of 3/16" steel-armored, single- conductor coaxial cable. The entire system is mounted in a 2000 Ford Excursion. Probes used in the MMV-04B corehole included the: 1) 2PFA-1000 Fluid-Temperature & Resistivity probe, made by MSI, 2) 2PGA-1000 combination Natural Gamma, Self-Potential (SP), Single-Point Resistance (SpR), and 8", 16", 32", 64" Normal Resistivity probe, made by MSI, 3) ABI-40 Acoustic Televiewer Probe, made by Advanced Logic and Technology (Luxembourg), and 4) Model 006-4002-204 Fluid Sampler, made by Mineral Logging Systems (MLS, Houston, TX).

The fluid temperature & resistivity (FTR) probe was calibrated at between 1.75 to 94.3 ohm-m and the temperature between 5.5°C and 63.8°C. These calibration values were used to log MMV-04B. Fluid conductivity is the inverse of resistivity and is more commonly reported. The fluid resistivity values used for calibration convert to 0.106 (94.3 ohm-m) and 5.70 mS/cm (1.75 ohm-m). The fluid sampler is approximately 8 feet in length and less than 2 inch O.D. with a sample capacity of 2 quarts. The operation of the fluid sampler is relatively simple. The sampler is a stainless steel probe, designed with the sampling tube at the bottom, and a plunger or valve that is machined for 2 o-rings. The valve is actuated up and down by applying negative or positive voltages to a worm gear. A series of portholes are located above the seated valve at the closed position, preventing fluid from entering the tube while going downhole. When the sampler is positioned at the desired depth, a negative voltage is applied to the probe, which opens the valve upward and above the ports, allowing fluid to fill the tube. The expulsion of air and replacement of fluid can occur rapidly and will likely be detected by the weight indicator on the winch, or by a sudden jerking of the logging vehicle. New o-rings were also installed prior to logging to ensure a tight seal. A food grade silicone (Dow Corning 111 compound) valve lubricant was applied to the new o-rings, which is necessary to prevent the seals from being pulled out of their seats during operation, and to further help to ensure a tight seal.

The logging order for this borehole was chosen in part due to the drilling method and drilling fluid circulation used by the drilling contractor. The drilling method was wireline coring. The drilling contractor used fresh water and open-loop circulation. Thus, bentonite was not used in the borehole, nor were formation cuttings (muds) recirculated in the borehole. The geophysical logging sequence was planned to record data in the following order: 1) fluid temperature & resistivity, 2) gamma, SP, SpR, 8", 16", 32" & 64" normal resistivity, and 3) acoustic televiewer (ATV). Because the probes have little clearance in the corehole, they tend to mix the water in the borehole as the probes move in the borehole. Thus, the FTR was run to minimize the disturbance of the borehole fluids.

The first set of logs was recorded on February 24, 2009 (Tuesday evening). The depth of the hole was approximately 255 feet below ground surface (bgs). The logging followed packer testing which was conducted at 50 feet intervals. FTR, gamma, SP, SpR, 8, 16, 32 & 64 inch normal resistivity measurements were run in case the borehole collapsed. Borehole stability was a concern because collapse and/or squeezing of shale and coal intervals is a relatively common occurrence in small-diameter boreholes in Pennsylvanian bedrock. Packer testing adds to the risk of borehole collapse.

The hole was logged a second time on February 27, after reaching a depth of 504 feet bgs. The HQ core rod was pulled completely out of the corehole to allow for openhole logging. The ATV probe uses 2 centralizers and cannot advance within the HQ casing due to its diameter and the weight of the probe. Logs were recorded in the sequence mentioned previously. However, during this stage of logging, the probes would not go beyond a depth of 314 feet. The hole was possibly bridged by a coal/underclay/shale interface that overlies a limestone. We speculate that the overlying materials may have been softened during the drilling of the harder limestone. An attempt was made to break thru the bridged interval with each probe, but refusal occurred at approximately the same depth each time.

In the morning (Feb 28), the driller pushed through this zone using only the weight of the drilling rod. The drilling rod was set at a depth of 326 ft to allow logging from 330 ft to TD and later raised to 286 ft to allow logging from 330 to 310 ft (the missed interval). Logging was then conducted a third time, approximately 10.5 hours after the second round of logging. Instead of starting with the FTR probe on this attempt, logging began using the gamma, resistivity, SP, SpR probe because it weighs more than the FTR probe, allowing it to more easily breach any potential bridged or collapsed intervals. The ATV probe could not be used because the HQ rod was used to keep the hole open. Data from all three logging runs were merged and are presented as a single log (Figures 1-3).

The FTR log shows fluid temperature, fluid resistivity, and fluid conductivity (Figures 1 and 2). The fluid conductivity (left side in Figures 1 and 2) increases smoothly from the surface to approximately 290 ft bgs (1.2 mS/cm), then increases more sharply until the sudden shift at 317 ft bgs. Fluid conductivity jumps off-scale at a depth of 317 ft. The maximum conductivity value recorded on the log was 126 mS/cm. The conductivity/resistivity data went off-scale (reported as negative value) at 317.3 ft bgs. At 317.2 ft bgs, the resistivity was recorded at 0.06 ohm-m and conductivity at 155 mS/cm. At 317.1 feet, the conductivity was 3.2 mS/cm. This apparently reflects a very sharp & distinct boundary within the fluid column. After the drilling rod was raised to 286 ft, the sharp break in fluid conductivity also shifted upward, to a depth of 314.7 ft (Figure 2).

Using the original FTR log (lighter traces in Figure 1), fluid samples were collected using a discrete interval sampler at 380 ft and then at 300 ft. The 380 ft sample was collected first and was thought to represent water with higher TDS. The 300 ft sample was collected to represent the upper end of the “briney” water column. The water quality of these samples is discussed in the **Fluid Samples** section.

Estimation of Formation Water Quality

Other geophysical logs (ATV, natural gamma, SP, SPR, & resistivity) are shown from ground surface to TD in Figure 3. Resistivity logs can be used to estimate fluid resistivity. Several researchers have published methods to compute salinity or TDS based on resistivity specifically for wells completed in the Illinois Basin (Pryor, 1965; Poole et al., 1989; Jorgensen, 1995; and Schnobelen et al., 1989). Using the natural gamma, SP, SPR, temperature, and resistivity (16 and 64 inch normal) logs, intervals were selected to compute the formation water resistivity (Rw). Porous intervals were selected (Table 2). Fresh water was used as the drilling mud in MMV-04B, and it had a wellhead temperature of 38.3°F. The conductivity of the "drilling mud" was measured at 0.21 mS/cm (Table 3); consequently the resistivity for mud fluid (Rmf) was calculated to be 47.62 ohm-m. Based on the temperature from the logs, Rmf at the formation temperature was calculated using a modified correction from Jorgensen (1995):

$$R2 = R1\,[(T1 + 6.77)/\,(T2 + 6.77)]$$

where T1= temperature at the well head
T2= formation temperature
R1= resistivity of drilling mud (Rmf) at the ground surface
R2= resistivity of drilling mud (Rmf) in the formation

Rw is the resistivity of the formation fluid and is a function of the formation temperature, the concentration of ions, and the ion species. Assuming normal fluid invasion (Z= 0.075), Rw can be calculated:

$$Rw = RtRz/Ri \text{ and } 1/Rz = (Z/Rw) + (1 - Z/Rmf)$$

where Rt= resistivity of the formation in the uninvaded zone (matrix and fluid not affected by drilling fluid) measured by the 64" normal log
Rz= resistivity of fluid in transition zone (resistivity of formation fluid between flushed and uninvaded zones)
Ri= resistivity of formation matrix and fluid in the transition zone measured by the 16" normal log
Rmf = resistivity of mud filtrate or the fluid in the flushed zone corrected to formation temperature (R2 from the equation above)

TDS was estimated from Rw by use of two nomographs from Poole et al. (1989), which were used to compute salinity and then TDS. Salinity is reported as a sodium chloride equivalent.

Table 2. Water quality estimated from resistivity logs in MMV-04B

Depth interval (ft)	**Lithology**	**Rw (ohm-m)**	**Estimated TDS (mg/L)**	
			Salinity as NaCl equivalent (mg/L)	**TDS (mg/L)**
336-345	Limestone (?)	8.98	700	700
359-367	Limestone	0.68	>10,000	>10,000

Fluid Sampling

As discussed above, fluid samples were collected in the borehole using a using a discrete interval sampler. The sample collected at 380 feet, showed high TDS by hand-held meter (Orion 130) and lab testing (Table 3). The 300 foot sample showed low TDS by hand-held meter (Orion 130) and lab testing. In addition, grab samples of the water used during drilling were tested —clean drilling water which was obtained from an ADM hydrant and the drilling return fluid (water used to displace the cuttings back to the ground surface). Both of these fluids had low specific conductance (<1 mS/cm) throughout the four days of coring. Detailed chemical analysis for the 380 ft and 300 ft samples are listed in Table 4.

Table 3. Specific Conductance and TDS of various samples

Sample	Specific Conductance (mS/cm)	TDS* (mg/L)
300 ft sample	3.2	1,550
380 ft sample	40.9	25,300
Drilling return fluid (depths ranging from 150 to 500 ft)	0.24 – 0.69	
Drilling water (water from ADM)	0.21 – 0.23	

*: TDS analysis determined by Prairie Analytical Systems, Inc., Springfield, IL on March 10, 2009

Estimation of Hydraulic Conductivity

Packer testing is a technique that allows one to estimate hydraulic conductivity (K) without the installation of a monitoring well. Another technique to estimate K involves the use of a spinner flowmeter, but this method requires a stable borehole. The Pennsylvanian bedrock in central Illinois is widely known for poor borehole stability, which we experienced in this project. Seven packer tests were conducted using pressures of approximately 20 and 40 psi above hydrostatic pressure (Table 5). These tests show that the rock had very low hydraulic conductivity.

Each packer test was conducted in three 18-minute segments—low pressure, high pressure and low pressure. These tests were conducted using a double packer system owned and operated by Raimonde Drilling Corp. The packer assembly fits in the bottom of the core barrel. The upper packer seals the drilling rod, while the lower packer seals the rock. Water flows down the drilling rod, through the packers and into the test interval. The packer test data were analyzed using Moye (1967) and Hvorslev (1951). Both methods provided similar values, but the higher value is reported in the table. These packer test results show the low hydraulic conductivity (K) of the tested bedrock. Many tests resulted in zero flow at pressures of 20 and 40 psi above hydrostatic pressure. Of the ten estimates, K values ranged from 3.1×10^{-8} to 2.7×10^{-6} cm/sec. All tests had K $< 1 \times 10^{-4}$ cm/sec, which is part of the definition of an underground source of drinking water (USDW).

For the packer tests which had “zero take”, the hydraulic conductivity can be estimated to be $< 10^{-8}$ cm/sec if you assume that a small, but unmeasureable volume of water actually flowed into the rock. For this estimate, this assumed volume was 0.05 gallons, which is one-half of the volume gage’s smallest increment.

MMV-01B is located approximately 1800 ft southeast of MMV-04B and is completed at a depth of 126 to 200 ft below ground surface. Using a recovery test and analyzing the data with Hvorslev (1951), the hydraulic conductivity of bedrock was estimated to be 3.1×10^{-5} cm/sec. The K estimated from the recovery test is higher than the K that could be estimated by Test 1 ($< 10^{-8}$ cm/sec). This could indicate:

1) The bedrock is heterogeneous across the site.
2) The shallower bedrock in MMV-01B has higher K than the deeper bedrock tested in MMV-04B.
3) K determined after well development will exceed K determined by packer testing.

Table 4. Chemical composition of water samples collected from MMV-04B on March 2, 2009 to determine lowermost USDW at Archer Daniels Midland (Decatur IL) as part of the Illinois Basin- Decatur Project. MMV-04B1 was collected from 380 feet and MMV-04B2 was collected from 300 feet using a wireline discrete sampling tool.

Constituent	MMV-04B1 380 ft sample (mg/L)	MMV-04B2 300 ft sample (mg/L)	Drinking Water Standard (mg/L)
Al	0.070	0.224	NA
As	<0.108	<0.108	0.010
B	0.706	0.496	NA
Ba	1.66	0.0363	2
Be	<0.00055	<0.00055	0.004
Ca	586	6.26	NA
Cd	<0.012	<0.012	0.005
Co	<0.013	<0.013	NA
Cr	<0.0058	<0.0058	NA
Cu	<0.00079	<0.00079	1.3
Fe	0.0237	0.0271	0.3
K	47.0	4.67	NA
Li	0.353	<0.018	NA
Mg	275	3.19	NA
Mn	0.862	0.0076	0.05
Mo	<0.022	0.064	NA
Na	9250	661	NA
Ni	0.141	<0.014	NA
P	<0.063	<0.063	NA
Pb	<0.041	<0.041	0.015
S	13.6	14.9	NA
Sb	<0.059	<0.059	NA
Se	0.157	<0.131	NA
Si	2.02	1.42	NA
Sn	<0.086	<0.086	NA
Sr	30.2	0.139	NA
Ti	<0.0056	0.00101	NA
Tl	0.025	<0.017	0.002
V	<0.047	<0.047	NA
Zn	0.0308	<0.0073	5
F	0.21	1.22	2
Br	35.4	2.90	NA
Cl	16830	875	NA
SO_4	32.1	40.0	250
SO_4 by cal. of S	40.7	44.6	NA
pH	7.91	9.09	6.5-8.5
EC (Ms/cm)	39.9	3.14	NA
Alkalinity (mg/L as $CaCO_3$)	79.0	129	NA
TDS (measured)	27,243- ISGS 25,300 - PA	1,876-ISGS 1,550- PA	500/10,000
TDS (calculated)	26,317	1,716	NA
TDS difference	1.04 ISGS[a] 0.96 PA	1.09 ISGS[a] 0.90 PA	NA
Anion/Cation Balance (%)	-2.3[a]	+2.0[a]	NA

ND= not determined

NA= not applicable or no standard

[a] = Within acceptable criteria for correctness of analyses (APHA. 1992, p.1-12)

Table 5. Summary of packer test results

Test #	Interval tested (ft)	Materials in tested interval	Pressure (psi)	Inflow (gals)	Hydraulic Conductivity (cm/sec)
1	162-194	Limestone, sandstone & other *(MMV-01 is screened in this interval)*	19	0	--
			39	0	--
			18	0	--
2	202-254	Various	27	0	--
			40	0	--
			25	0	--
3	252-304	Various	20	0.26	5.2×10^{-8}
			38	2.29	4.1×10^{-7}
			20	0	--
4	302-354	Various *(Driller noted that coal at 304' took water)*	20	0	--
			37	0.97	1.6×10^{-7}
			20	0	--
5	359-374	Carthage or Shoal Creek Limestone	22	5.8	**2.7×10^{-6}**
			41	1.6	6.7×10^{-7}
			22	0.17	7.8×10^{-8}
6	383-404	Inglefield and Trivoli Sandstones	20	0.11	3.6×10^{-8}
			35	0.01	3.1×10^{-8}
			18	0	--
7	412-454	Coal & West Franklin Limestone (top 13.5 of 18.5 ft)	18	0	--
			41	1.05	1.6×10^{-7}
			21	0.2	3.4×10^{-8}

Monitoring Well Design

Per the UIC permit requirements, ADM is required to monitor the lowermost underground source of drinking water. Based on the data collected in MMV-04B (Tables 3 to 5), the pore water appears to consistently exceed 10,000 mg/L TDS at a depth of 317 feet below ground surface (Figures 1 and 2). Thus, groundwater shallower than 317 ft should meet the water quality requirement. None of the tested bedrock met the hydraulic conductivity definition of a USDW.

As shown in Table 1, a limestone (309-324 ft) is found at a depth of 317 ft. This limestone appears to be brine filled. This limestone is overlain by gray shale (304-309 ft), black shale and coal (303 to 304 ft), interbedded sandstone and siltstone (299-303 ft), and fine-grained sandstone (266-299 ft). This fine-grained sandstone may be suitable for providing small volumes of water needed for geochemical monitoring. Packer testing indicated that the interval from 252 to 304 ft took some water during the test, so this is encouraging. The hydraulic conductivity of the sandstone may increase if any well skin is removed during well development.

The monitoring well was constructed with stainless steel casing and screen (Figure 4). The well's depth places it at the limit of the collapse pressure of PVC, so PVC casing was not used. Using a tremie pipe, the borehole was backfilled to a depth of 295 feet to provide a stable base for well construction. Bentonite pellets and noncalcareous gravel pack were used below 325 ft. Bentonite pellets were placed from 295 to 325 ft, which should adequately seal the sandstone (266-299 ft) from the briney water below. Other well specifications include—

Screened interval:	275-295 ft
Sand pack (silica or gravel pack):	265-295 ft
Bentonite chips/pellets:	262-265 ft
High solids bentonite grout:	2-262 ft
Cement (to hold well protector):	0-2 ft

References

Hvorslev, M .J., 1951. Time lag and soil permeability in ground-water observations, Waterways Experiment Station Bulletin No. 36, U.S. Army Corps of Engineers, Vicksburg, Mississippi, 50 p.

Jorgensen, D.G., 1995. The Ratio Method of Estimating Water Resistivity and TDS from Resistivity Logs, **Ground Water 34**(3): 519-522.

Moye, D.G., 1967. Diamond drilling for foundation exploration, **Civil Engineering Transactions 9**: 95-100.

Pryor, W.A., 1956. Quality of Groundwater Estimated from Electric Resistivity Logs, Illinois State Geological Survey Circular 215, 15 p.

Poole, V.L., K. Cartwright and D. Leap, 1989. Use of Geophysical Logs to Estimate Water- Quality of Basal Pennsylvanian Sandstones, Southwestern Illinois, **Ground Water 27**(5): 682-688.

Schnobelen, D.J., E.F. Bugliosi, and N. C. Krothe, 1995. Delineation of a Saline Groundwater Boundary from Borehole Geophysical Data, **Ground Water 33**(6):965-976.

Figure 1. Fluid temperature/resistivity log recorded in MMV-04B on February 27 & 28, 2009 by Tim Young, ISGS. Fluid conductivity (navy blue) is shown on the left side, while fluid temperature (red) and fluid resistivity (royal blue) are shown on the right side. Recorded interval is 0 to 484 feet below ground surface.

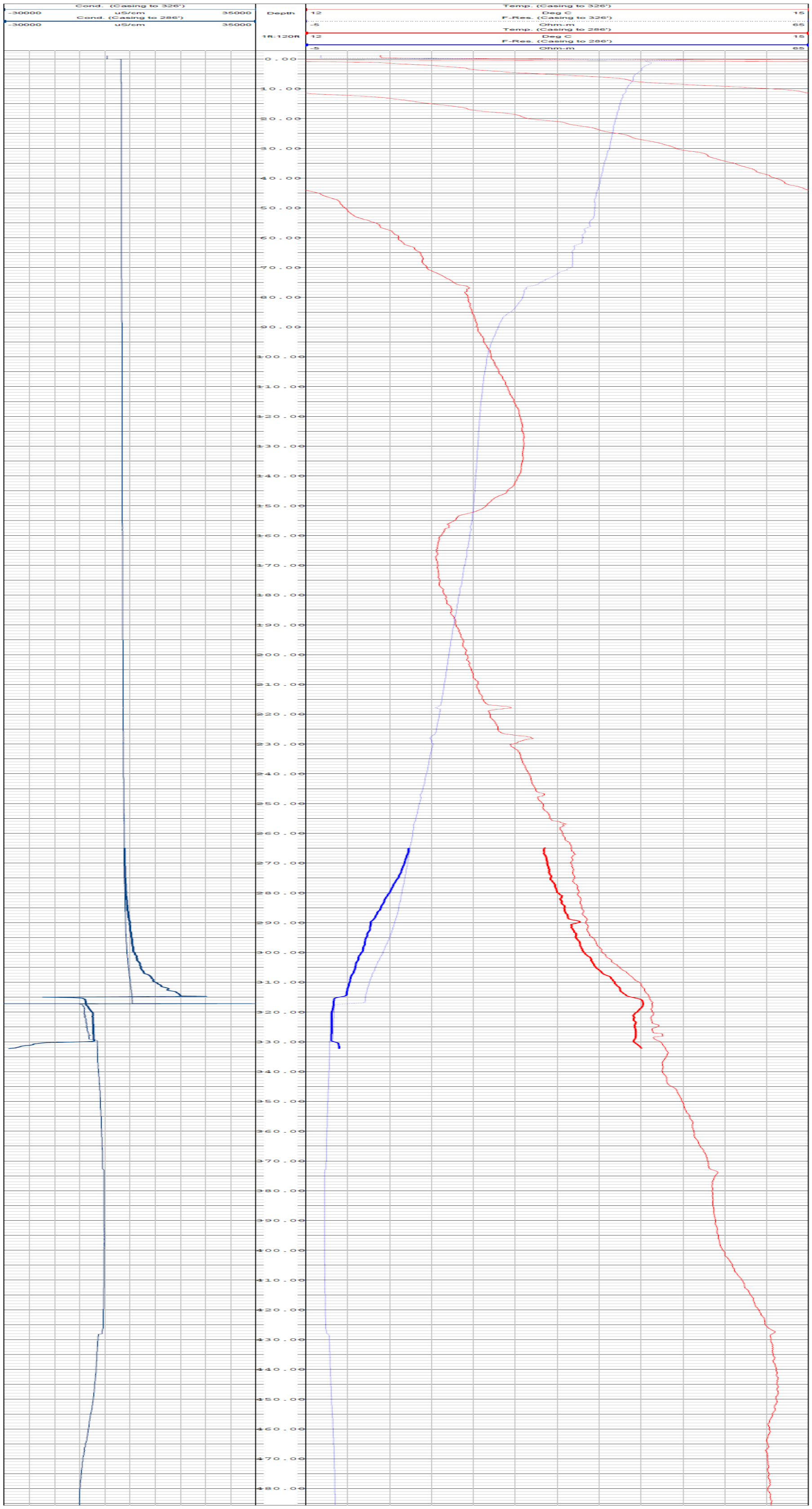


Figure 2. Fluid temperature/resistivity log recorded in MMV-04B on February 27 & 28, 2009 by Tim Young, ISGS. Fluid conductivity (navy blue) is shown on the left side, while fluid temperature (red) and fluid resistivity (royal blue) are shown on the right side. Recorded interval is 290 to 340 feet below ground surface.

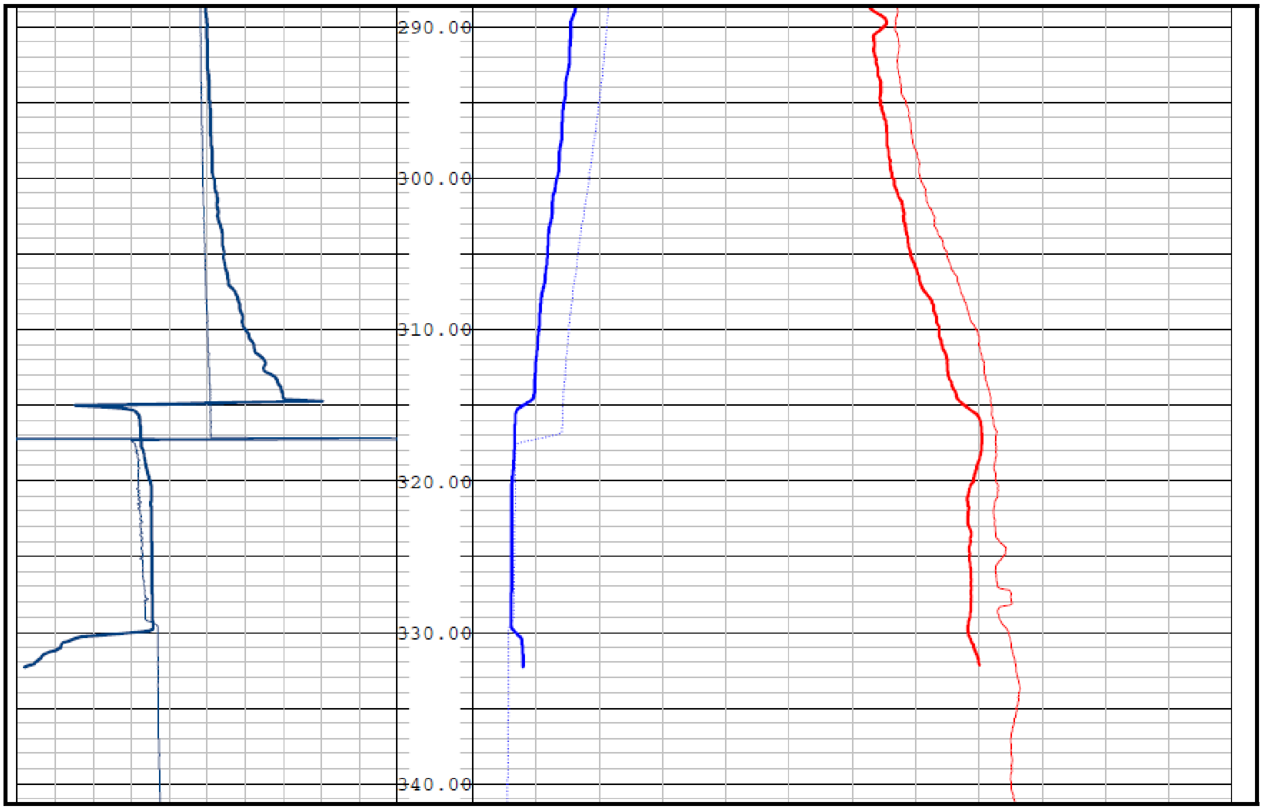


Figure 3. Polyprobe log recorded in MMV-04B on February 27 & 28, 2009 by Tim Young, ISGS. Acoustic televiewer, natural gamma, SP, SPR, and resis tivity (8", 16" 32" & 64") are shown. Recorded interval is 0 to 484 feet below ground surface.

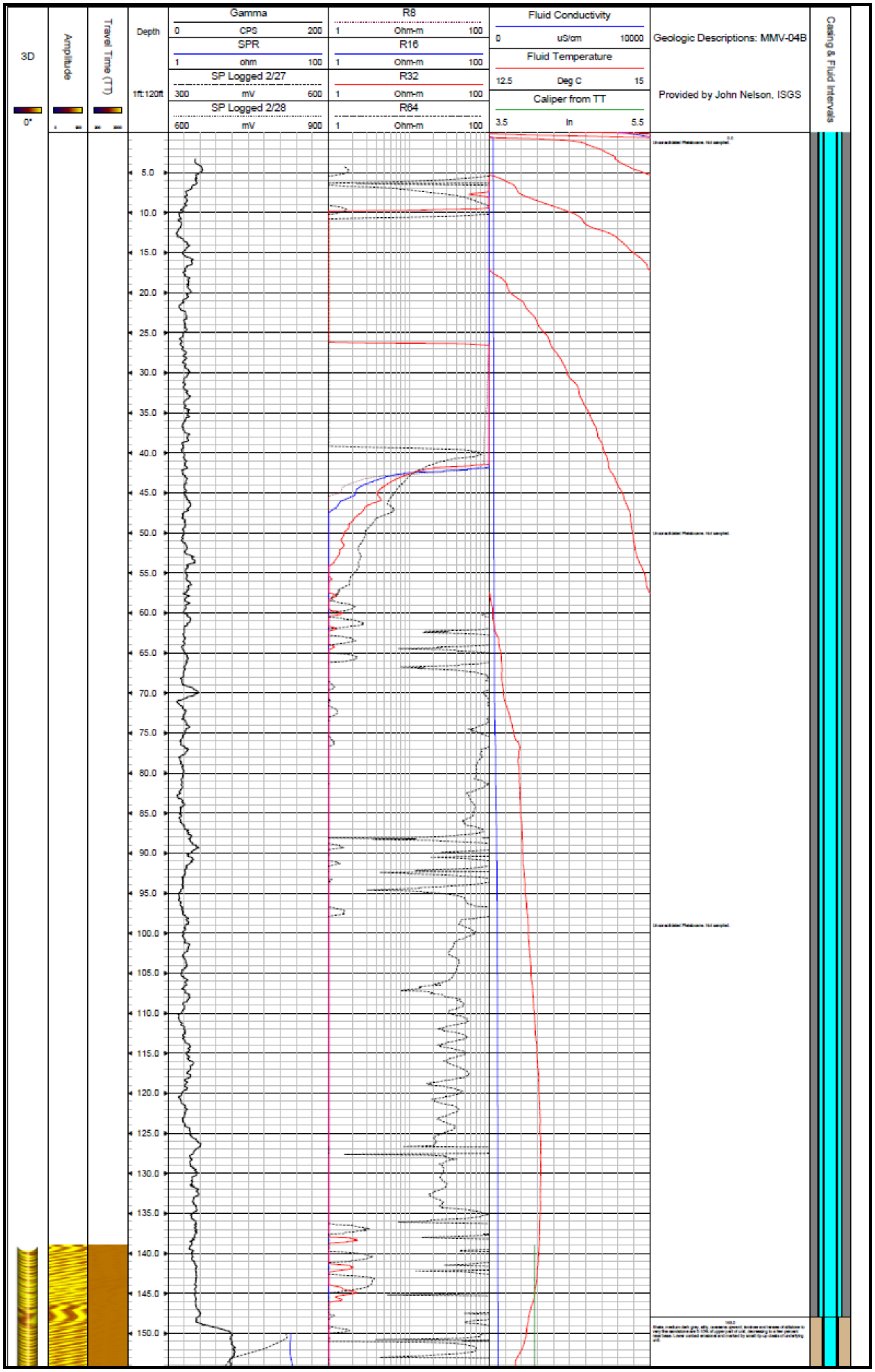


Figure 3. (continued)

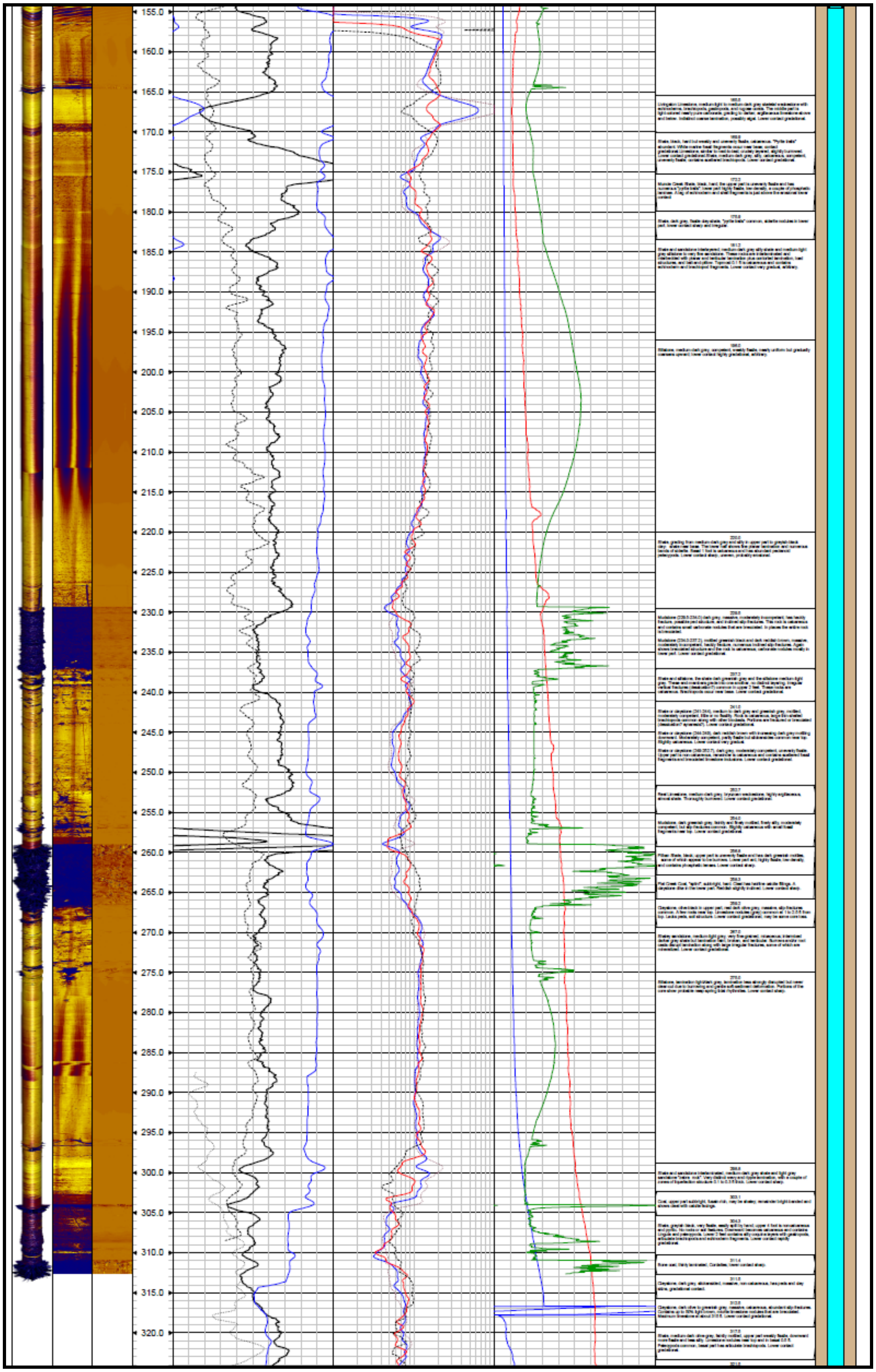


Figure 3. (continued)

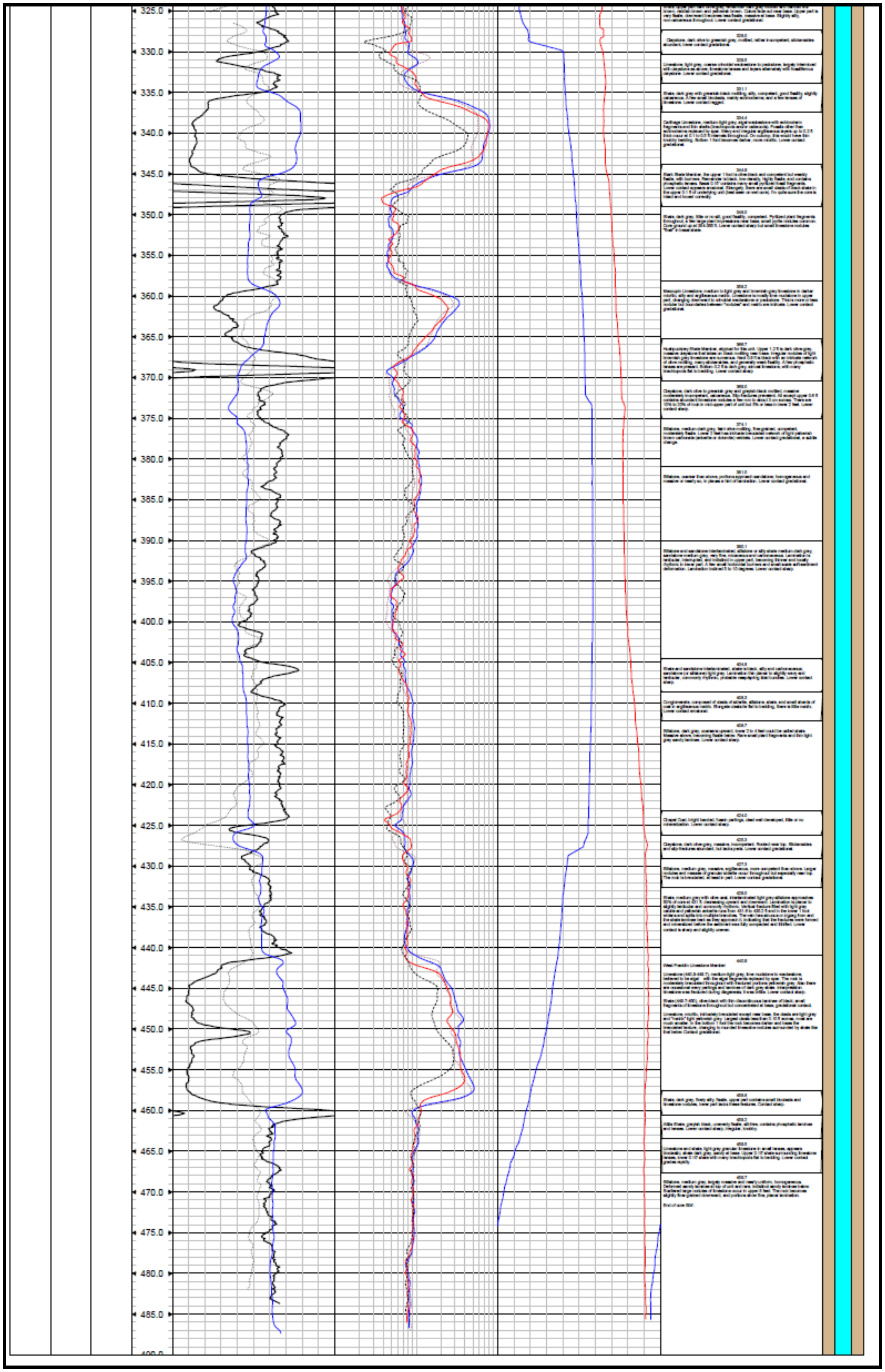


Figure 4. Construction details for MMV-04B

Illinois Environmental Protection Agency **Well Completion Report**

Site Number: 1150155136 County: Macon

Site Name: ADM Corn Sweeteners Plant 180 Well #: MMV-04B

State Plane Coordinate: X 826014.5 ft Y 1171093.3 ft (or) Latitude: ___ o ___ ' ___ " Longitude: ___ o ___ ' ___ "

Borehole #: 121152339600

Surveyed by: Edward Mehnert

IL Registration #: ____

Drilling Contractor: Albrecht Well Drilling (Ohio, IL)

Driller: Pat Dye

Consulting Firm: Illinois State Geological Survey

Geologist: Edward Mehnert

Drilling Method: Mud rotary

Drilling Fluid (Type): mud for glacial, water for rock

Logged By: Edward Mehnert

Date Started: 2/16/09 Date Finished: 3/13/09

Report Form Completed By: Edward Mehnert

Date: 3/26/09

ANNULAR SPACE DETAILS

Type of Surface Seal: concrete

Type of Annular Sealant: bentonite slurry

Installation Method: tremie pipe

Setting Time: 24 hours

Type of Bentonite Seal - - Granular, Pellet, Slurry (Choose One)

Installation Method: tremie pipe

Setting Time: 24 hours

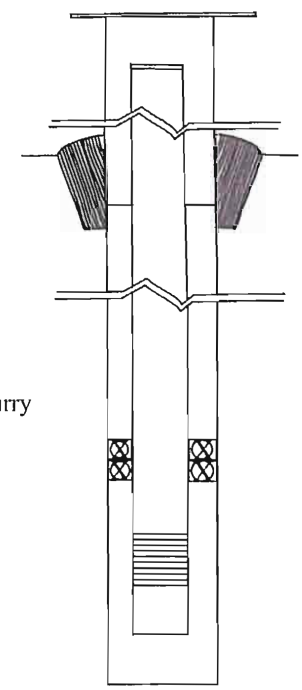
Type of Sand Pack: silica sand

Grain Size: 0.055" (Sieve Size)

Installation Method: tremie pipe

Type of Backfill Material: bentonite & pea gravel (if applicable)

Installation Method: tremie pipe



Elevations (MSL)*	Depths (BGS)	(.01ft.)
684.67	3.00	Top of Protective Casing
684.62	2.83	Top of Riser Pipe
681.67	0	Ground Surface
679.67	2.0	Top of Annular Sealant
626.68	54.99	Static Water Level (After Completion)
419.67	262.0	Top of Seal
416.67	265.0	Top of Sand Pack
406.67	275.0	Top of Screen
386.67	295.0	Bottom of Screen
386.67	295.0	Bottom of Well
386.67	295.0	Bottom of Borehole

* Referenced to a National Geodetic Datum

CASING MEASURMENTS

Diameter of Borehole (inches)	6.0
ID of Riser Pipe (inches)	2.0
Protective Casing Length (feet)	3.0
Riser Pipe Length (feet)	277.8
Bottom of Screen to End Cap (feet)	297.8
Screen Length (1st slot to last slot) (feet)	20.0
Total Length of Casing (feet)	277.8
Screen Slot Size **	10

**Hand-Slotted Well Screens are Unacceptable

WELL CONSTRUCTION MATERIAL

(Choose one type of material for each area)

Protective Casing	SS304, SS316, PTFE, PVC, or Other
Riser Pipe Above W.T.	SS304, SS316, PTFE, PVC, or Other
Riser Pipe Below W.T.	SS304, SS316, PTFE, PVC, or Other
Screen	SS304, SS316, PTFE, PVC, or Other

217/524-33300

December 2, 2009

Certified Mail
7004 2510 0001 8615 8534

Archer Daniels Midland Company
Attn: Mark Burau, Decatur Corn Plant Manager
4666 Faries Parkway
Decatur, Illinois 62526

Re: 1150155136 -- Macon County
ADM Company
ILD984791459
Permit No. UIC-012-ADM
Log No. PS09-206
Well No. CCS #1
UIC Administrative Record File
PS Corr

Dear Mr. Burau:

This is in response to a document submitted on behalf of ADM Company (ADM) by Dean Frommelt dated September 29, 2009 and received by the Illinois EPA on September 30, 2009. The subject document is a final report summarizing investigation results to determine the lowermost underground source of drinking water (USDW) in the vicinity of the ADM facility.

An Underground Injection Well (UIC) Permit effective January 27, 2009 was issued to ADM to construct an UIC well, known as Carbon Capture Sequestration Well No. 1 (CCS1). Pursuant to Section I of the UIC Permit ADM must install groundwater monitoring wells that will constitute the groundwater monitoring program associated with the injection well process for the UIC. These wells must be completed in the lowermost USDW.

The Illinois EPA has determined that it can approve the Pennsylvanian Bedrock as the lowermost USDW in the vicinity of the ADM facility. In addition, the Illinois EPA can approve the use of the verification well to collect groundwater data to serve as an early warning indicator of any CO_2 leaking from the Mt. Simon Sandstone as a result of the injection activities associated with ADM's UIC Permit. Therefore, the Illinois EPA can approve the subject submittal subject to the following conditions and modifications:

1. In accordance with Condition I.4.a of ADM's UIC Permit, within thirty (30) days of the installation and development of groundwater monitoring wells G101, G102, G103, and G104 ADM must submit additional information concerning the construction details to the

Illinois EPA. The additional information must be submitted as minor permit modification pursuant to 35 Ill. Adm. Code 704.264. These details include:

a. ADM Well Number;

b. Well Depth (Ft-bgs);

c. Well Depth Elevation (Ft-MSL); and

d. Well Screen Interval (Ft-MSL)

2. In accordance with Condition I.4.b of ADM's UIC Permit, construction of groundwater monitoring wells G101, G102, G103, and G104 must be in such a manner as to prevent the movement of fluids into or between underground sources of drinking water. The casing and cementing used in the construction of the wells must be designed for the life expectancy of the wells.

3. In accordance with Condition I.4.c of ADM's UIC Permit, construction G101, G102, G103, and G104 must be at a minimum in accordance with the diagram contained in Attachment F of the Permit, with the exception of the sandpack. The sandpack for groundwater monitoring wells G101, G102, G103 and G104 can be ≤ 5 feet.

4. Pursuant to Condition I.4.c of ADM's UIC Permit and due to the construction of groundwater monitoring well MMV-04B, the well cannot be used as a groundwater monitoring well for the lowermost USDW. In accordance with Condition I.4.h, all groundwater monitoring wells not utilized in the groundwater monitoring system, but retained by the facility, must be maintained in accordance with 35 Ill. Adm. Code 920 regulations.

5. All groundwater related activities must be conducted in accordance with Section I of the UIC Permit.

Work required by this letter, your submittal or the regulations may also be subject to other laws governing professional services, such a the Illinois Professional Land Surveyor Act of 1989, the Professional engineering Practice Act of 1989, the Professional Geologist Licensing Act, and the Structural Engineering Licensing Act of 1989. This approval letter does not relieve anyone from compliance with these laws and the regulations adopted pursuant to these laws. All work that falls within the scope and definitions of these laws must be performed in compliance with them. The Illinois EPA may refer any discovered violation of these laws to the appropriate regulating authority.

Should you have any questions regarding this submittal, please contact Terri Blake Myers, L.P.G. of my staff at 217/524-3284. If you any questions regarding other issues associated with the Permit, please contact Kevin Lesko at 217/524-3271.

Sincerely,

Stephen F. Nightingale, P.E.
Manager, Permit Section
Bureau of Land

SFN:TBM:mls/090383s.doc
w/w-TBM KDV

cc: Dean Frommelt, Division Environmental Manager -- ADM
Sallie Greenburg – Illinois State Geological Survey